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FOREWORD

I am pleased to put into the hands of readers Volume-8; Issue-4: July –August 2023 of **“International Journal of Environment, Agriculture and Biotechnology (IJEAB) (ISSN: 2456-1878)”,** an international journal which publishes peer reviewed quality research papers on a wide variety of topics related to **Environment, Agriculture and Biotechnology**. Looking to the keen interest shown by the authors and readers, the editorial board has decided to release issue with DOI (Digital Object Identifier) from CrossRef also, now using DOI paper of the author is available to the many libraries. This will motivate authors for quick publication of their research papers. Even with these changes our objective remains the same, that is, to encourage young researchers and academicians to think innovatively and share their research findings with others for the betterment of mankind.

I thank all the authors of the research papers for contributing their scholarly articles. Despite many challenges, the entire editorial board has worked tirelessly and helped me to bring out this issue of the journal well in time. They all deserve my heartfelt thanks.

Finally, I hope the readers will make good use of this valuable research material and continue to contribute their research finding for publication in this journal. Constructive comments and suggestions from our readers are welcome for further improvement of the quality and usefulness of the journal.

With warm regards.

Editor-in-Chief
Date: September, 2023

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Transcriptomic analysis of *Hevea brasiliensis* seedlings under supplemental LED night lighting

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***Abstract*— *Hevea brasiliensis is an important economic crop which produces natural rubber. Supplemental LED night lighting improves its growth, however the underlying molecular mechanism remains unknown. The study analyzed the transcriptome of H. brasiliensis plants under the treatment of LED night lighting. The light treatment resulted in 1047 and 411 differentially expression genes (DEGs) during the day and night time, respectively. Functional group analysis showed that DEGs in the day time enriched into 185 metabolic pathways and that DEGs in the night time enriched into 116 metabolic pathways. A total of 92 DEGs were identified between night lighting and control plants. These DEGs were involved in regulation of pigment metabolism, photosynthesis, circadian rhythm, and carbohydrate metabolism. The genes associated with circadian rhythm were altered during the day and night time. The gene involved in carbohydrate metabolic process was upregulated and the related KEGG pathways associated carbohydrate metabolism were upregulated. These results concluded that supplemental LED night lighting improve growth of hevea plants by upregulating genes associated with photosynthesis and carbohydrate metabolism, so as to synthesize more carbohydrates.*

***Keywords*— rubber tree, seedling culture, photoperiod, circadian rhythm, molecular mechanism**

I. INTRODUCTION

The Para rubber tree (*Hevea brasiliensis* Müll. Arg.) is the sole source of commercial natural rubber worldwide. Due to its economic and industrial importance, China plants more than 10 million hectares of rubber trees. However, as China belongs to non-traditional zone for rubber tree growing, the growth speed of rubber tree in China is much lower than that in traditional zones. This is because China encounters low temperature in winter, which constrains the growth of rubber trees. It generally takes more than 8 years for the trees to attain the girth required for tapping (50 cm) in China. This is much longer than the time required in traditional zones (approximately 5–6 years). The low growth speed in China thus increases the time required for propagating planting materials (grafted seedlings). Around 18-20 months are needed for producing planting materials by green budding. It is much longer than the time needed in Southeast Asian countries.

Light is one of the key environmental factors regulating plant growth and development. As light provides energy for photosynthesis, limited light conditions could be a constraining factor for plant growing. Supplemental lighting during the night extends the photoperiod, which enables increased photosynthesis and thus promotes plant growth. Light-emitting diode (LED) lamps are the preferred source for supplemental lighting due to their low operating temperature, durability and low cost (Singh et al., 2015). Supplemental night lighting has been widely used in the production of crops and other plants to promote growth and quality (Fukuda et al., 2000, 2004, Okushima et al., 2012, Zhou et al., 2031, Kweon et al., 2016, Tewolde et al., 2016). Our earlier studies have been demonstrated that supplemental LED night lighting can improve the growth of rubber trees by accelerating rhythmic growth of shoots (Yao et al., 2021a, b). The rhythmic growth of rubber tree is endogenously controlled (Hallé et al., 1978), however the underlying molecular mechanism is not clear. In this study, the transcriptome profile of plants under LED night lighting was investigated to uncover the molecular mechanism relative to growth accelerating under extended photoperiods.

II. MATERIALS AND METHODS

Plant materials and experimental design

One year old grafted plants (clone CATAS 73397) were subjected to LED night lighting from 20th December, 2021. The supplemental lighting time during the night was from 18:00 PM to 06:00 AM. LEDs were hung 0.5 m above the plants. The lamp spectrum was red and blue combined with a photosynthetic photon flux density (PPFD) of 150 μmol m^{-2} s^{-1} measured at 50 cm from the LED lamps. Plants without night lighting were used as control plants. Three repeats were designed for night lighting and control plants, respectively. Each repeat was composed of 15 plants. After one month, leaves from top flush were collected for transcriptome sequencing. Sample were collected at two time points, 10:00 and 22:00. Leaves were immediately frozen in liquid nitrogen and then stored at -80℃ until for RNA extraction. Three samples were collected from corresponding repeats.

RNA preparation, transcriptome sequencing, and assembly

Total RNAs of leaf samples were extracted with TRIzol reagent (Invitrogen) according to the manufacturer's protocol and quantified using Qubit® RNA Assay Kit and the Qubit® 2.0 Flurometer (Life Technologies). RNA degradation and contamination were monitored on 1% agarose gels; the purity and integrity were assessed using the NanoPhotometer® spectrophotometer (IMPLEN) and the RNA Nano 6000 Assay Kit of the Agilent Bio analyzer 2100 system (Agilent Technologies), respectively.

Sequencing library construction and Illumina sequencing were performed by Novogene Technology Co., Ltd (Beijing, China). After filtering out the adaptor sequences and deleting low-quality and contaminated reads, we assembled leaf transcriptomes using Trinity with min_kmer_cov set to 2 by default and all other parameters set default.

Differential gene expression and pathway analysis

Differential expression analysis of LED treatment and the control was performed using the DESeq2 R package (1.20.0). The resulting P-values were adjusted using the Benjamini and Hochberg's approach for controlling the false discovery rate. Genes with an adjusted P-value <=0.05 found by DESeq2 were assigned as differentially expressed. Analysis of and enrichment was tested by Fisher's exact test. Clusterprofiler software was used to perform Gene Ontology (GO) function enrichment analysis and Kyoto Encyclopedia of Genes and Genomes (KEGG) pathway enrichment analysis. Based on *Hevea* genome database, gene function annotation was performed using cluster transcriptome sequences and public databases, and the differential genes were annotated into gene sets in GO or KEGG databases.

III. RESULTS AND DISCUSSION

Transcriptome sequencing and sequence assembly

To investigate the genes associated with LED night lighting response, a total of 12 leaf samples were collected from two treatments at two time points for transcriptome analysis. Summary of sequence assembly after illumine sequencing was shown in Table 1. Generally, around 42-49 million clean reads comprising 6.32-7.32 Gb were obtained from 12 samples. The GC content of sequences was about 43% and the error rate was about 3%. More than 92% of the bases had a Phred quality score greater than 30 (Q30). These indicated that the quality of the sequencing data was acceptable and that this sequencing data could be used for transcriptome analysis.

Differentially expressed genes during the day and night times

The DEGs between LED night lighting and control plants were identified by the DEGseq of the R package (Version 1.12.0) with qvalue<0.005 and |log2FoldChange|>1 as the thresholds. A total of 1047 DEGs were identified during the day time, with 584 genes upregulated and 463 genes downregulated in night lighting plants compared with control plants (Figure 1-A). While during the night time, a number of 411 DEGs were identified, with 208 genes upregulated and 203 gene downregulated (Figure 1-B). These DEGs indicated that LED night lighting affected gene expression patterns in leaves, with larger changes occurring at the day time.

Analysis of GO terms

The GO was used for gene annotation and analysis, which included molecular functions, cellular components and biological processes three ontologies. The DEGs of day time were classified into 477 GO terms, of which 15 GO terms were significantly different. The upregulated DEGs of day time were classified into 370 GO terms, among of which 197 were related to biological processes, 30 were related to cell components, and 143 were related to molecular functions. Among the 370 GO terms, eight terms were significantly upregulated (Figure 2), with three relating to cell components (extracellular region, extracellular matrix, and extracellular region part), five relating to molecular functions (iron ion binding, oxidoreductase activity, heme binding, tetrapyrrole binding, and UDP-glycosyltransferase activity). The downregulated DEGs of day time were classified into 308 GO terms, among of which 156 terms were related to biological processes, 9 terms were related to cell components, and 143 terms were related to molecular functions. Nine of the 308 GO terms were significantly upregulated, all belonging to molecular functions (Figure 3).

The DEGs of night time were classified into 331 GO terms, of which 10 GO terms were significantly different. The upregulated DEGs of night time were classified into 285 GO terms, among of which 157 were related to biological processes, 14 were related to cell components, and 114 were related to molecular functions. The downregulated DEGs of night time were classified into 104 GO terms, among of which 56 were related to biological processes, 13 were related to cell components, and 35 were related to molecular functions. Among the 104 GO terms, 16 terms were significantly upregulated, four were related to biological process and 12 were related to molecular functions (Figure 4).

Analysis of KEGG pathways

The DEGs were analyzed for KEGG pathway enrichment. A number of 611 differently expressed genes in the day time were enriched into 185 pathways, of which 4 pathways were significantly upregulated. The upregulated genes (378 genes) of day time were enriched into 151 pathways, three pathways being significantly upregulated (Figure 5). The most two upregulated pathways were photosynthesis-antenna proteins and circadian rhythm, both of which were related to photoperiod. This indicated that night lighting obviously affected the expression of genes involving photoperiod. The upregulated pathway of photosynthesis-antenna proteins suggest that the photosynthetic efficiency may enhance and more carbohydrates may be synthesized. The downregulated genes (233 genes) of day time were classified into 108 pathways. A total of 185 DEGs in the night time were enriched into 116 pathways. The upregulated genes (99 genes) in the day time were enriched in 63 pathways, while the downregulated genes (86 genes) were enriched in 71 pathways.

Identification of DEGs involved in LED night lighting

DEGs during the day and night time were further analyzed to identify genes involving LED night lighting. A total of 92 DEGs were found at both time points (Figure 6). Among these 92 DEGs, four genes were upregulated and 11 genes were downregulated (Figure 7). One downregulated gene (*scaffold0610_634905*) was annotated to be chlorophyllase, which involved in pigment metabolic process. Three downregulated genes (*scaffold1092_104788*, *scaffold0713_578123*, *scaffold0205_1475163*) were related to terpene synthase, which was associated with isoprene, a matter for rubber biosynthesis. Five downregulated genes were involved in eight GO terms, one belonging to biological process classification and 7 belonging to molecular function classification. Of the four upregulated genes, one (*scaffold0598_393375*) was a transcription factor (MYB 11), and one gene (*scaffold0528_875561*) was annotated to involve in carbohydrate metabolic process. The upregulated gene *scaffold0528_875561* was associated with 8 KEGG pathways, including carbon metabolism, carbon fixation in photosynthetic organisms, fructose and mannose metabolism, pentose phosphate pathway, and gluconeogenesis. Three downregulated genes were associated with three different KEGG pathways, one involving in chlorophyll metabolism, another involving in diterpenoid biosynthesis, the last involving in circadian rhythm.

Our earlier result showed that supplemental LED night could affect chlorophyll content in the leaves (Yao et al., 2021b). The transcription result in this study confirmed that the expression of genes associated with chlorophyllase and chloroplast were affected under LED night lighting. Therefore the change of chlorophyll content could be the result of gene expression. Photoperiod is associated with the genes of circadian rhythm. Supplemental LED night lighting lengthened the photoperiod and the expression of genes associated with circadian rhythm could be changed. The KEGG pathway of circadian rhythm-plant was different during the day and night time. Eleven genes involved in circadian rhythm-plant pathway were upregulated at the day time, but two genes were downregulated during the night time. Supplemental LED night lighting also may affected the process of rubber biosynthesis. Three downregulated genes at the day and night times were involved in terpene synthase, which associated with the GO term of terpene synthase activity. These genes also involved in diterpenoid biosynthesis pathway.

Our earlier studies demonstrated that the extended photoperiod by supplemental LED night lighting could promote *hevea* plants growth (Yao et al., 2021a, b). It could speculate that more carbohydrates could be synthesized because of supplemental LED night lighting. The transcript profile of this study showed that the gene involved in carbohydrate metabolic process was upregulated at the two time points. What is more, five KEGG pathways associated with carbohydrate metabolism were upregulated during the day and night time.

IV. CONCLUSIONS

Hevea brasiliensis grows slowly in the tropical regions of China because of relatively low temperature during winter. Supplemental LED night lighting could improves its growth. The transcription profile here identified the expression of genes associate with accelerated growth. The genes associated with pigment metabolism and carbohydrate metabolism were upregulated. The corresponding GO terms and KEGG pathways were thus upregulated. Therefore, more carbohydrates were synthesized and the growth were improved. The genes involved in circadian rhythm were also differently expressed at the day and night time. This study confirms the growth improvement of *hevea* young plants under supplemental LED night lighting from a molecular aspect. The study also suggests that it is recommended to apply supplemental LED night lighting to improve the growth of *hevea* seedlings during winter.

Table 1 Summary of sequencing data after filtering

sample	Raw reads	Clean reads	Raw bases	Clean bases	Total map %	Error rate	Q20 %	Q30 %	GC %
LD1	48,827,730	48,787,646	7.32G	7.32G	94.69	0.03	97.42	92.55	43.06
LD2	47,114,834	43,579,168	7.07G	6.54G	95.17	0.03	97.76	93.61	43.04
LD3	49,359,616	45,477,976	7.40G	6.82G	95.36	0.03	97.85	93.40	43.14
CD1	47,496,154	43,679,378	7.12G	6.55G	94.75	0.03	97.52	92.77	42.88
CD2	46,571,432	42,944,306	6.99G	6.44G	94.49	0.03	97.38	92.46	42.82
CD3	46,858,718	42,831,574	7.03G	6.42G	94.73	0.03	97.25	92.13	42.88
LN1	46,043,174	42,489,634	6.91G	6.37G	94.61	0.03	97.32	92.32	42.92
LN2	46,239,978	43,115,966	6.94G	6.47G	94.64	0.03	97.71	93.47	42.94
LN3	46,116,426	43,018,910	6.92G	6.45G	94.80	0.03	97.56	93.14	42.92
CN1	50,647,248	48,015,888	7.60G	7.20G	94.22	0.03	97.58	93.21	44.63
CN2	50,040,584	45,539,310	7.51G	6.83G	94.44	0.03	97.56	92.84	42.96
CN3	47,724,436	43,265,408	7.16G	6.49G	95.03	0.03	97.57	92.66	42.98

LD: samples collected from LED night lighting plants at day time; CD: samples collected from control plants at day time; LN: samples collected from LED night lighting plants at night time; CN: samples collected from control plants at night time.

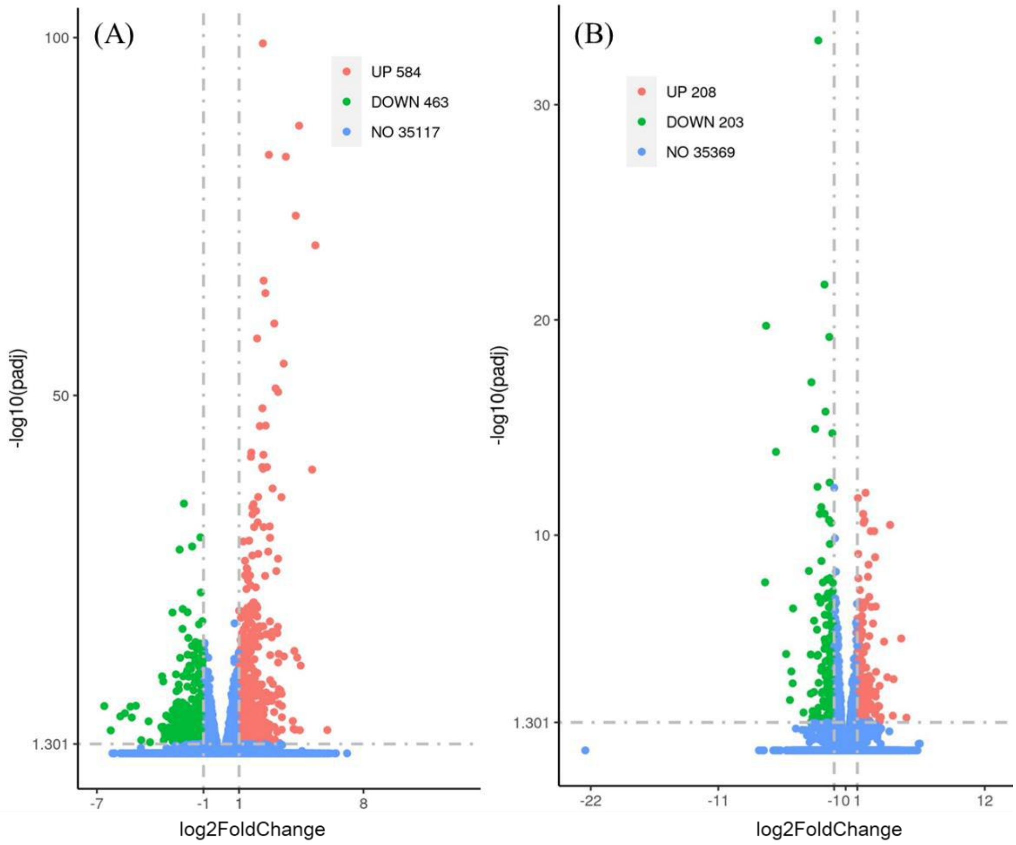

Fig.1. Volcano plots of DEGs at day time (A) and night time (B)

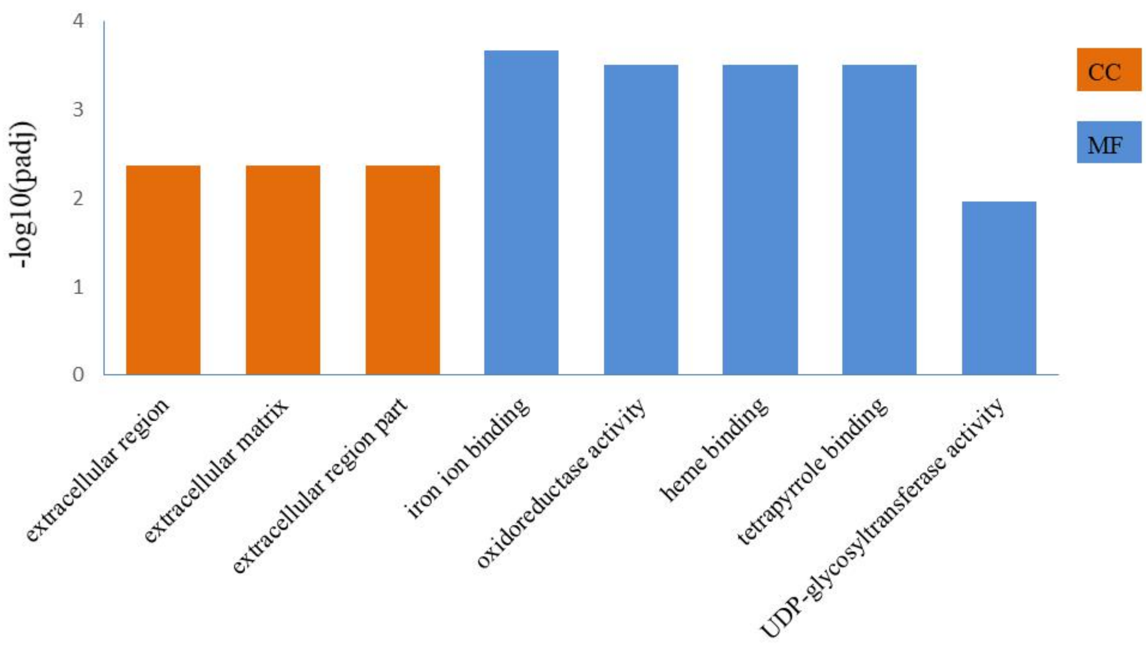

Fig.2. Upregulated GO terms at the day time

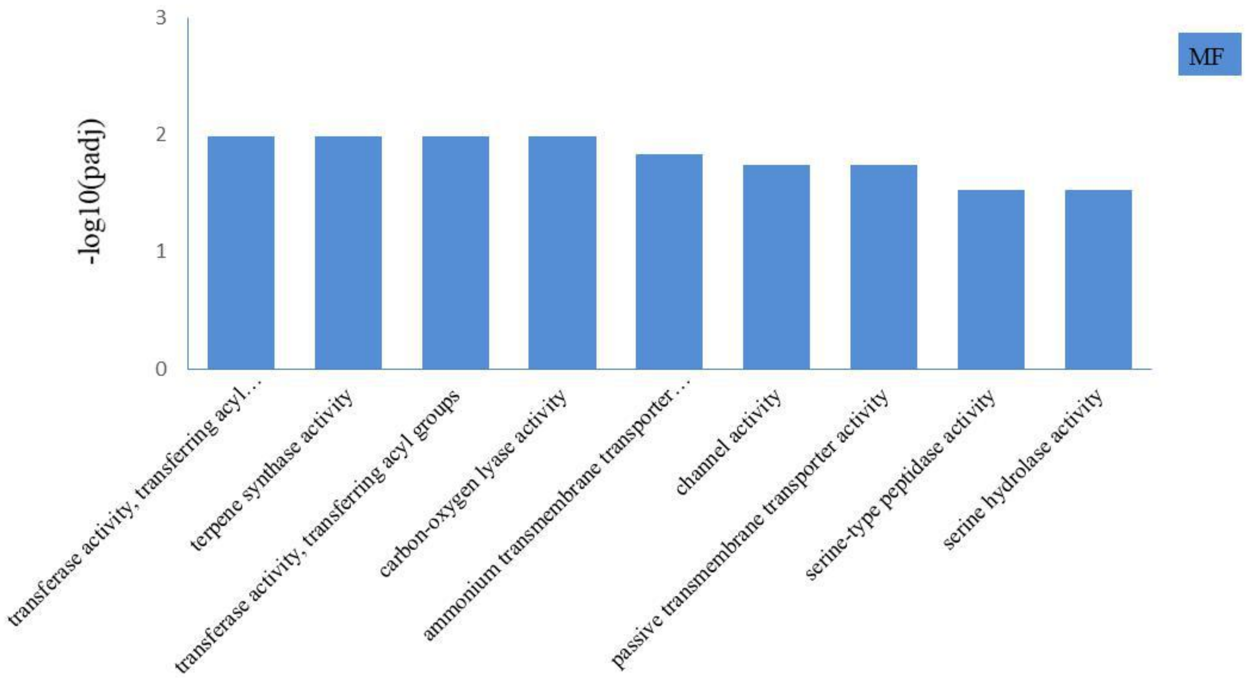

Fig.3. Downregulated GO terms at the day time

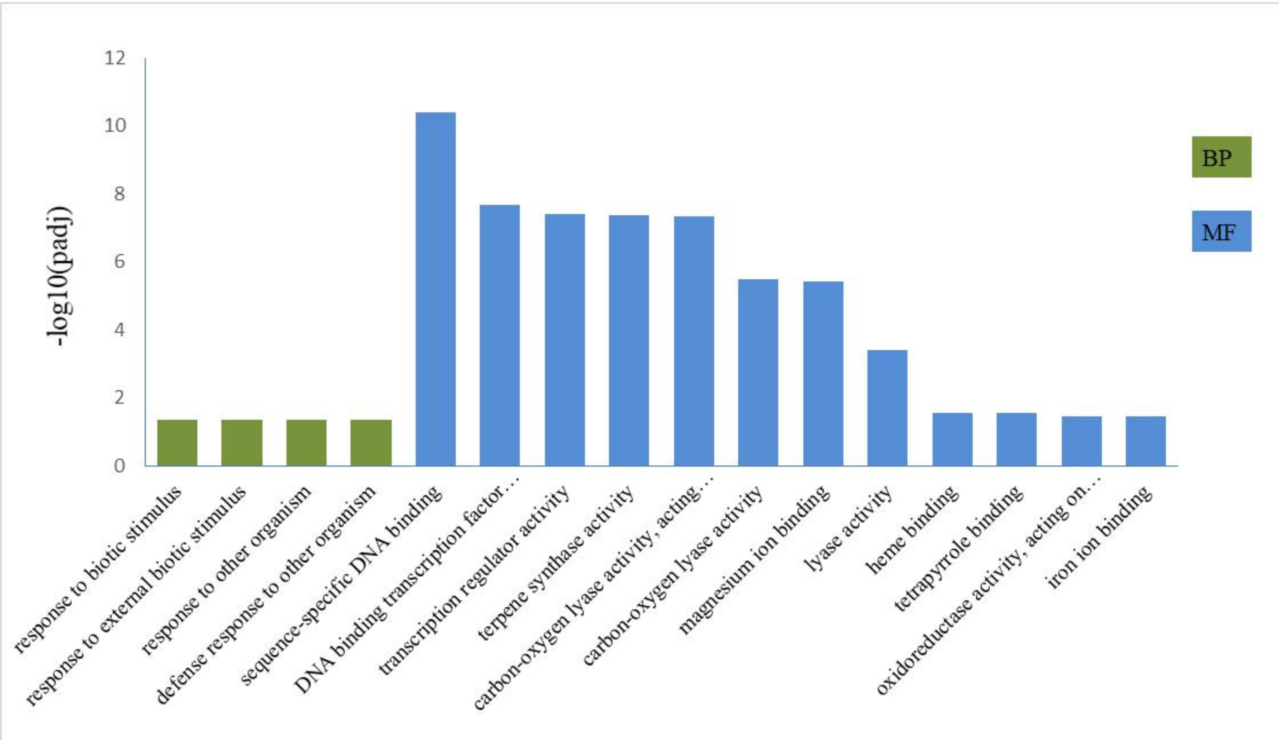

Fig.4. Downregulated GO terms at the night time

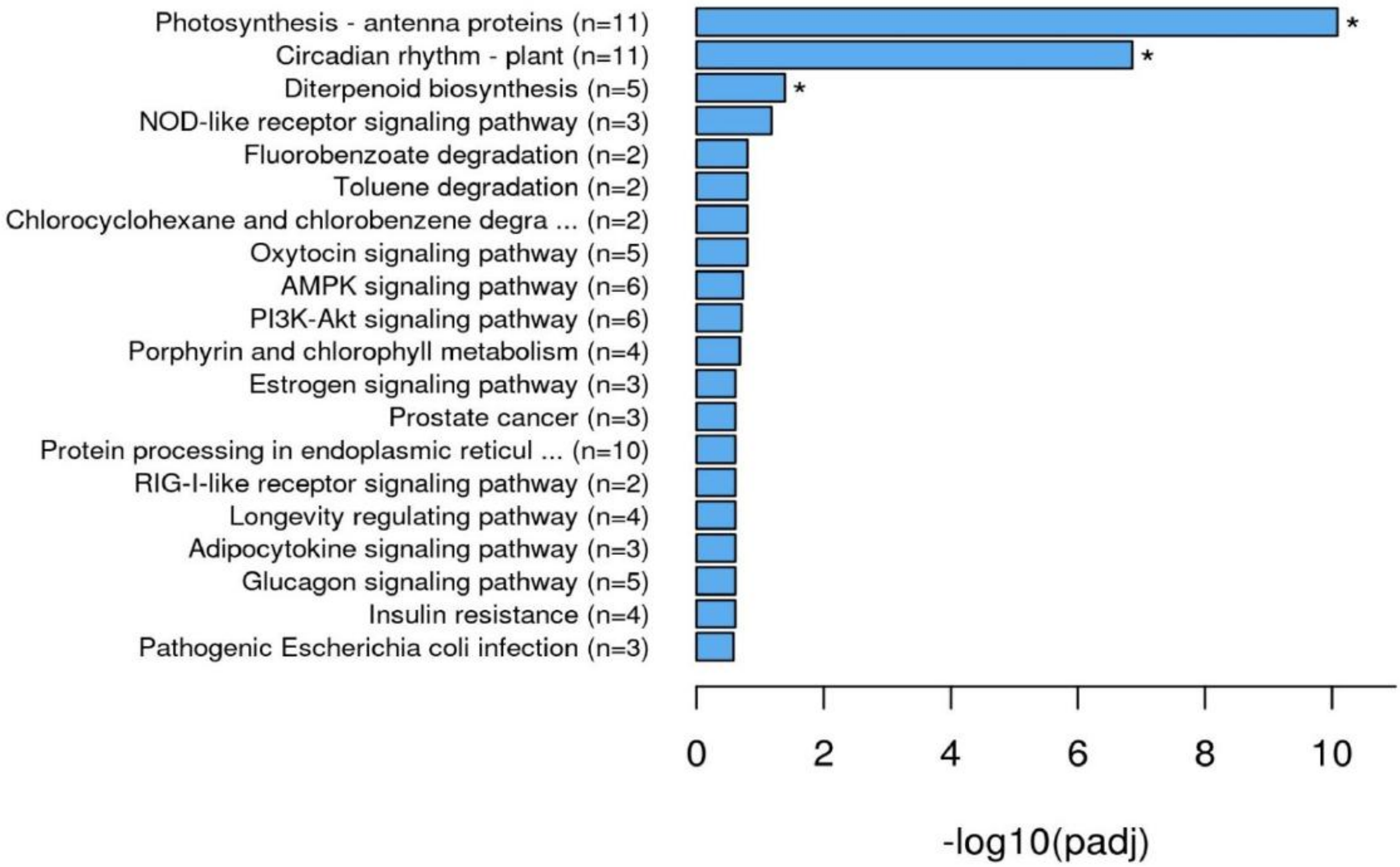

Fig.5. KEGG pathway enrichment map of DEGs at the day time

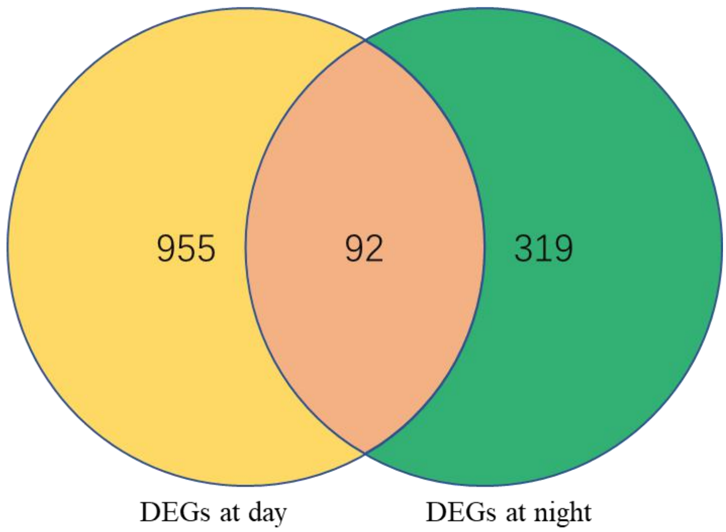

Fig.6. Venn diagram showing all DEGs at day time and night time

(each row corresponds to a gene, the color of every cell indicates the expression level based on z-score normalization.)

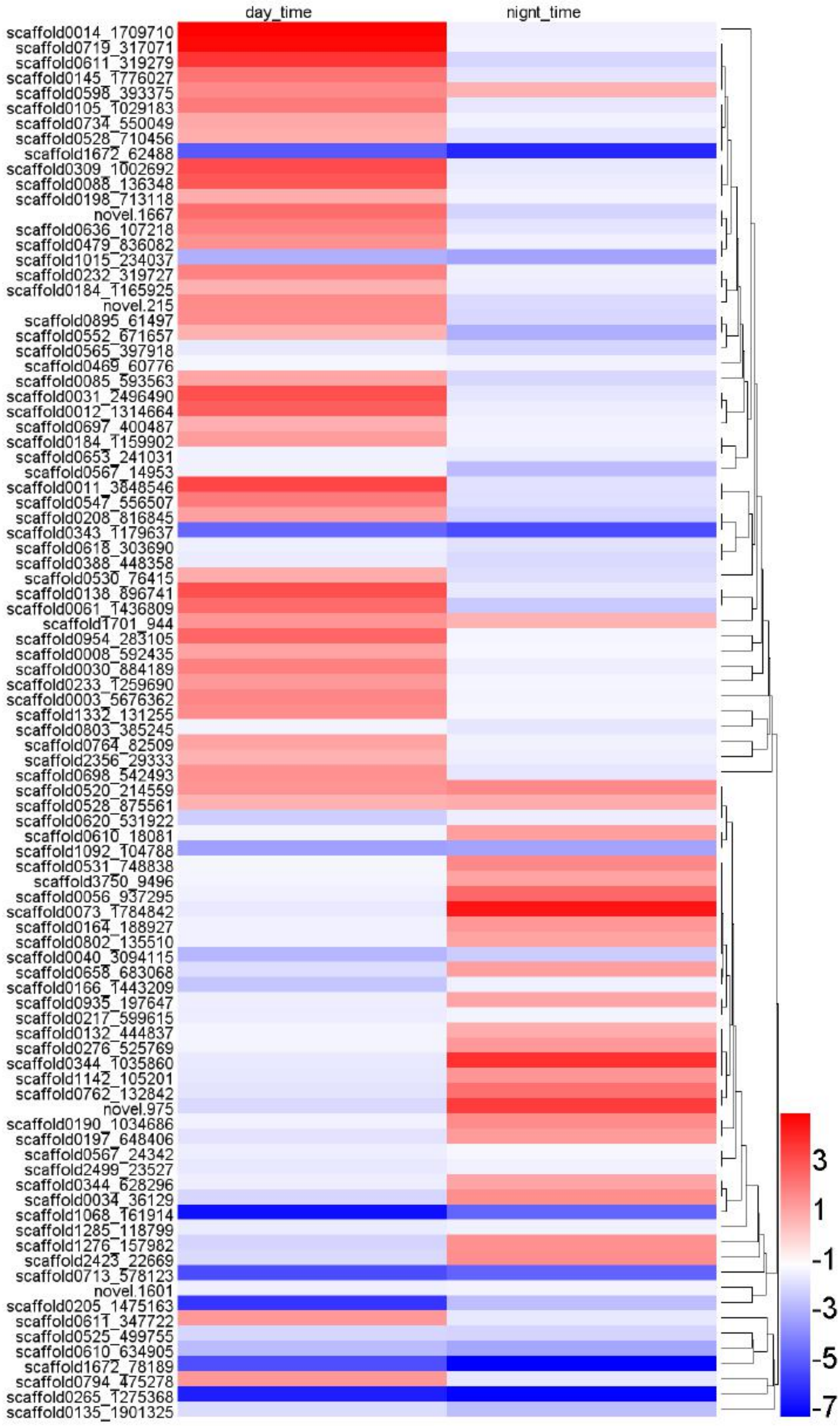

Fig.7. Heatmap of 92 DEGs at the day and night time.

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Diversity and structure of woody stands in the contracted vegetation of western Niger following a rainfall and anthropisation gradient

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Abstract— *The aim of this study was to characterise the diversity and structural parameters of the woody stand in the contracted vegetation of western Niger at three sites located along a rainfall and human settlement gradient. An inventory of the woody flora and a measurement of the dendrometric characteristics of the trees were carried out on 120 plots of 2500 m2 subdivided into plots 12.5 m apart. The species richness was 17 species in 9 genera and 12 families on all the sites investigated, with 11 species on the Kouré plateau, 13 on the Guittodo plateau and 17 in the Gorou Bassounga classified forest. Density was 234.79, 555.09 and 683.79 ind/ha, basal area 4.21, 7.2 and 8.62m2/ha and tree cover 19.8, 45.34 and 60.75¨%, respectively on these three sites. In terms of structure, the stand has a high proportion of relatively young individuals. Shannon's diversity (2.37 to 2.81 bits) indicates that the environments are of low diversity and Pilou's equitability (0.56 to 0.63) highlights a phenomenon of dominance in the three stands. The lowest similarity index (0.44) is obtained between the Kouré plateau and the Gorou Bassounga classified forest, and the highest (0.46) between the Kouré plateau and the Guittodo plateau. These results testify to the low diversity and young structure of this dying vegetation.*

Keywords— ***contracted vegetation, anthropic pressure, density, basal area, cover***

I. INTRODUCTION

The ecosystems of West Africa have undoubtedly been shaped by man for thousands of years (Wittig et al., 2002). The continuing degradation of vegetation cover is partly due to population growth and climatic factors (Wezel and Haigis, 2000). Anthropogenic influence on the evolution of vegetation is a source of threat to the survival of many useful species (Lykke et al., 1999; Hahn-Hadjali and Thiombiano, 2000) and locally accentuates the causes of ecological imbalance. This degradation of ecosystems and species richness is also one of the consequences of the arid climate (Thiombiano, 2005). Thus the drying up of the climate has led to a rapid transformation of ecological and social systems (Mahé and Paturel, 2009). This situation affects not only Sahelian regions, but also areas that are usually more humid (Grouzis and Albergel, 1989). In fact, natural resources are undergoing intense degradation as a result of physical, agro-climatic and/or anthropogenic factors (Rognon, 2007). Niger is no exception to this situation. It is prey to episodic droughts marked by the dieback of ligneous plants (Morou et al., 2016). This aridity is compounded by the devastating actions of man, particularly in contracted formations. Every year, an average of 60,000 ha of contracted forests on the plateaux of Niger are cleared (Ichaou, 2000). These forests are essential for local communities, which derive a large part of their economy from wood exploitation (Moussa et al, 2018). This degradation is manifested by changes in the floristic composition, structure and density of the vegetation (Bakhoum, 2013). The alternative to this degradation has been the introduction of regulatory provisions to protect forest land (Abdourhamane et al., 2013). Rural timber markets involving local people in management were set up in the 1990s to better organise and control logging. However, the high demand for wood energy resulting from strong population growth and the dysfunction of the management structures put in place have not enabled the trend to be reversed. It is clear that data on structure and diversity provide indicators for analysing trends in the qualitative and quantitative evolution of vegetation (Ouédraogo, 2006), and composition and structure vary considerably from one locality to another as a function of environmental factors and human disturbance (Blanc et al., 2000). Several recent studies (Morou, 2010, Lassina et al., 2011; Moussa et al., 2013; Diouf, 2012, José Luis et al., 2013; Rabiou, 2016, Idrissa et al., 2019) have been carried out in the zone, but their general nature does not allow us to specify the diversity and parameters of the vegetation.

II. MATERIALS AND METHODS

1.1 Study area

The study area corresponds to the Iullemenden basin located to the east of the River Niger, which encompasses the regions of Tillabéry, Dosso and the urban community of Niamey (Ichaou, 2000). They have a population of around 5,787,043 (INS, 2012) and are among the most densely populated areas of Niger. In this part of Niger, plateaux make up the bulk of the landscape, characterised by contracted plant formations. In places, there are shrub and tree savannahs and shrub steppes. Average annual rainfall varies from 350 mm in the extreme north (Kouré) to 800 mm in the extreme south (Gaya).

1.2 Choice of study sites

In order to better characterise this vegetation, three (3) sites were chosen according to a North-South climatic gradient and a decreasing degree of anthropisation (Figure 1). These sites were chosen on the basis of the existence of contracted vegetation on the plateau, the degree of anthropisation and their location along a rainfall gradient. The Kouré plateau, highly anthropised, located in the rural commune of Kouré (Tillabéry) at latitude 13°19′35″ N and longitude 2°37′15″ E. The Guittodo plateau, less anthropised than Kouré, is located in the rural commune of Farey (Dosso) at latitude 12°31'45"N and longitude 3°15'07"E. The Gourou Bassounga classified forest, which is less anthropised than the first two sites, is located in the extreme south-west of Niger, towards the Niger-Benin border at latitude 11°58′04″N and longitude 3°22′48″ E, part of which is in the commune of Gaya and the other in that of Tanda.

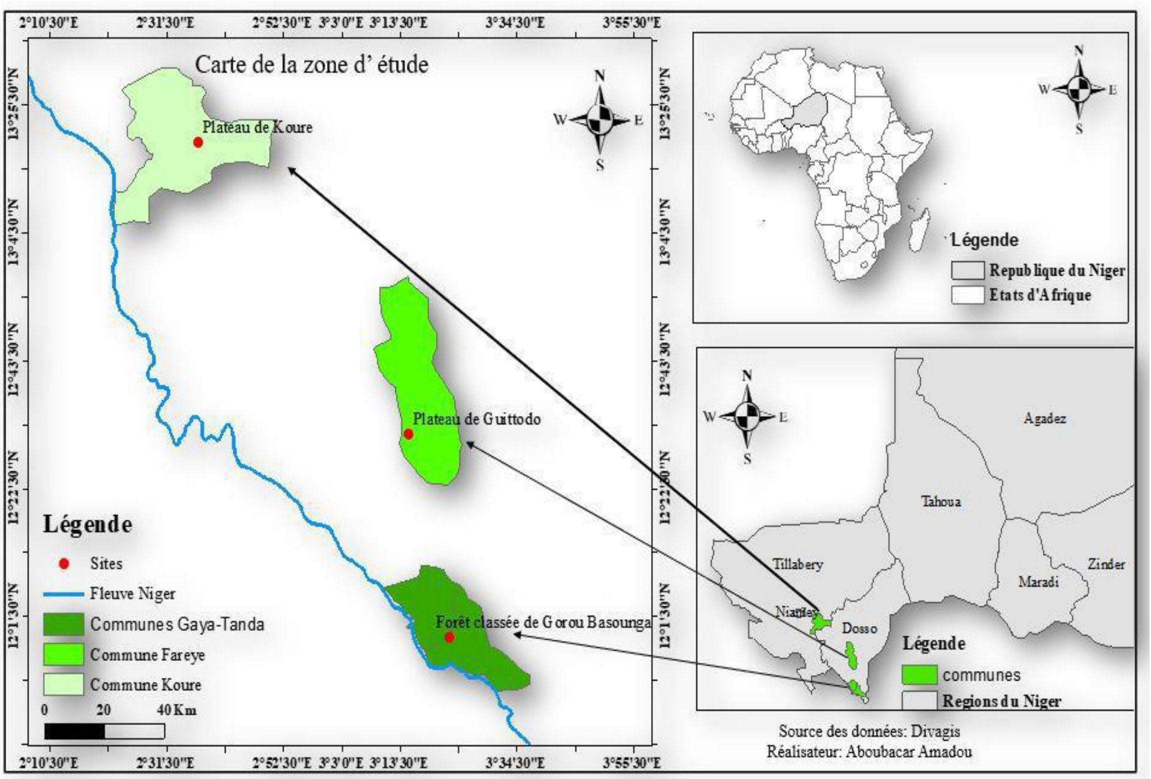

Fig.1: Location of study sites

1.3 Installation of the inventory system

Floristic surveys were carried out using the system proposed by Couteron et al. (1995) and recommended by the proceedings of the Niamey workshop for the inventory of contracted formations (SUN-UE, 2008). This system (Figure 2) respects the spatial configuration of the patterns of contracted formations. A pattern comprises a bare strip and a strip of vegetation with each sub-unit. The bare strip comprises parts: a= upstream and b= downstream of this bare strip and the vegetation strip comprises parts: c= an upper fringe or settling zone, d= furrow and e= lower fringe or snag fringe (SUN-UE, 2008).

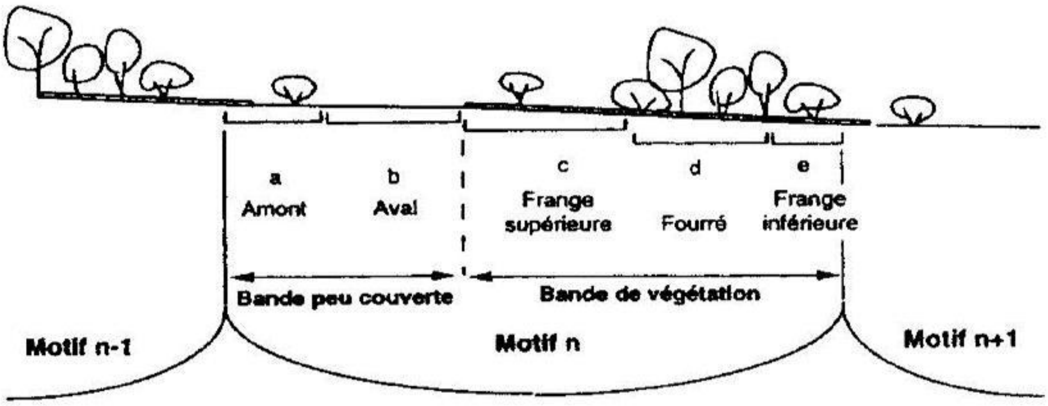

Fig.2: System proposed by Couteron et al in 1995 (SUN-UE, 2008)

1.4 Collection of inventory data

The data were collected in October and November 2021, corresponding to the start of the dry season. During this period of the dry season, when the herbaceous plants begin to dry out, the woody plants are still in full leaf (Fournier, 1991). It is therefore the most favourable period for collecting data on woody plants. Sampling was based on random transects, which according to (Gounot, 1969) allow the greatest diversity of the environment to be taken into account. On each site, five (5) transects were chosen at random. These transects are parallel and follow the steepest slope, with variable lengths depending on the natural spacing of eight successive wooded strips previously fixed per transect. Rectangular plots measuring 100mx25m were placed in the vegetated strips and arranged perpendicular to them to take into account variation in woody density (Thiombiano et al. 2016). Eight (8) plots were placed per transect at a rate of 40 plots per site, for a total of one hundred and twenty (120) plots. To facilitate data collection, the 2500m2 plots were subdivided into 12.5m x 12.5m plots as recommended by (SUN-UE, 2008) for contracted formations. A total of 640 plots were used to collect dendrometric data on each site. For the diameter measurements, the minimum exploitable diameter was taken into account, which is 4cm for contracted formations. Diameter measurements (<4m) are considered as belonging to regeneration (SUNU 2008). Measurements were taken of adult ligneous trees of all species. Heights (<7m) were measured using stakes and heights (>7m) using a Suunto clinometer. Trunk diameters were measured at 1.3 m using a forestry compass and/or caliper (Photo 1). The diameters of the crown on two (2) perpendicular axes were measured using a tape measure.

Photo 1: Height and diameter measurements of woody plants

1.5 Data analysis and processing

The density, which is the ratio of the total number of adult individuals in the sample (N) to the area sampled (S) per hectare, was calculated using the formula: D= N/S where N = total number of trees in the plots and S = area sampled (Ngom et al., 2013);

Total species richness (S) is the total number of species in the stand considered in a given ecosystem (Ramade, 2003).

The average species richness corresponds to the average number of species per survey for a given sample (Ramade, 2003);

Basal area was calculated as the tree area assessed at the base of the tree trunk using the formuler: $G=\frac{\Pi}{40000XS}\sum_{i=1}^{n} di^2$ (Rondeux, 1999), where S= plot area and di = diameter of trunk i at 0.3 m ;

The Lorey height (HL) is the average height of the individuals weighted by their basal area and is obtained by the formuler, $HL=\frac{\sum_{i=1}^{n} gi*hi}{\sum_{i=1}^{n} gi}$, where $gi= \frac{\Pi}{4} di^2$ (Rondeux, 1999);

Cover was calculated as the area of the tree crown projected vertically to the ground obtained by the formuler = $\frac{\sum \pi(\frac{d_{mh}}{2})^2}{S_E}$, where dmh = average crown diameter in m; S_E = sample area in hectare (Ngom et al., 2013).

The Shannon-Weaver Diversity Index (H) was calculated using the formuler $H=\sum_{i=1}^{s} pi \log_2 pi$, with Pi = ni/N, where Pi=frequency of the species (i); ni =number of individuals of the species, s=total number of species and N=total number of individuals (Rondeux, 1999). Diversity is low when H is less than 3 bits, medium if H is between 3 and 4 bits, and high when H is greater than or equal to 4 bits (Frontier and Pichod, 1995).

Pielou equitability is calculated using the formuler: **E=H/Hmax,** where H is Shannon's diversity index and Hmax is the maximum diversity index. If E ∈ [0 -0.6] then Piélou equitability is low (dominance phenomenon existing in the community). If E ∈ [0.7 -0.8] then Pielou's equitability is average. If E ∈ [0.8 -1] then Pielou equitability is high (absence of dominance in the community) (Garba et al, 2017).

The Sorensen Index is calculated using the formuler K = 2C / (2C + A + B), where A= number of species from list a (site A), B= number of species from list b (site B), C= number of species common to both sites (A and B) (Thiombiano et al. 2016).

The Family Importance Value Index (FIV) is calculated using the formuler FIV = relative dominance + relative density + relative diversity. All the information gathered on the families is included in this index. It provides information on the floristic importance of each family, the number of individuals in the family out of the number of species in the family and the quantitative importance of the family in terms of basal area. It is the sum of three factors representing the quantitative biometric value of the survey per hectare (Mori et al 1985).

The Species Importance Value Index (IVI) is a synthetic and quantified expression of the importance of a species in a stand. It provides a better appreciation of the importance of species in a plant community. The SVI is defined as the sum of relative dominance (Domr), relative frequency (Fr) and relative density (Dr), which are calculated using the following formuler:

IVI = Domr + Fr + Dr (Baggnian et al., 2019), with:

$$Domr = \frac{\text{Total basal area of species}}{\text{Basal area of all species}} x\ 100$$

$$Fr = \frac{\text{Species frequency}}{\text{Sum of species frequencies}} x\ 100$$

$$Dr = \frac{\text{Number of individuals of the species per ha}}{\text{Total number of individuals per ha}} x\ 100$$

These three factors vary between 0 and 100%, while the IVI, which corresponds to the sum of the three factors representing the quantitative biometric values of the species, varies between 0 and 300% and highlights the most important species. Species with an IVI ≥ 20% are those ecologically important (Traore et al, 2012) and were retained as dominant and their demographic trend was established. Stand structure: The theoretical Weibull distribution was used because of its great flexibility of use and presents a great variability of forms according to the values taken by its theoretical parameters (Bullock, 2005). It has three parameters (position a, scale or size b and shape c and its probability density function f (x) is: $F(x) =\frac{c}{b}(\frac{x-a}{b})^{c-1} \exp(-(\frac{x-a}{b})^c)$. Parameter a corresponds to the threshold value which is the smallest diameter value; parameter b is linked to the central value of the diameter class distribution and parameter c to the observed structure which, depending on its value, leads the Weibull distribution to take several forms. A test of the fit of the observed distribution to the theoretical Weibull distribution (Rondeux, 1999) was carried out using Minitab 16 software.

III. RESULTS

2.1 Species richness

Species richness is one of the main characteristics of a plant stand and is the measure most frequently used to study woody plant biodiversity. The species richness was (17) species, distributed between 9 genera and 12 families over all three sites investigated. It increases along the rainfall gradient, with (11) species on the Kouré plateau, (13) on the Guittodo plateau and (17) in the Gorou Basounga classified forest, which is home to all the species inventoried. The average species richness was 4.70 species for the study area, with 3.4 in Kouré, 4.77 in Guittodo and 5.95 in Gorou Bassouga. The variance in mean species richness was 2.77 in the study area, with 1.14 in Kouré, 2.3 in Gorou Bassounga, and an intermediate value of 1.63 in Guittodo, indicating an increase along the rainfall gradient (Table 1).

Table 1: Variation in specific richness

Parameters	Koure Plateau	Guittodo Plateau	Gorou Bassounga Forest	Study sites
Specific richness (S)	11	13	17	17
Mean species richness (s)	3,4	4,77	5,95	4,70
Variance of (s)	1,14	1,63	2,30	2,77

2.2 Comparison of dendrometric parameters

The results (Table 2) show that the values of all the parameters examined increase with the rainfall gradient and decrease with the level of human settlement. Overall analysis of the results shows that there is a significant difference (P<0.05) between the different sites (photo1) for density, diameter, Lorey height (HL), basal area and crown cover.

Table2: Results of multiple comparison tests of the means of dendrometric parameters according to sites

Dendrometric parameters	KP	GP	GBCF	Probability
Density (Individuals/ha)	234,79±23,9[b]	555,09±21[b]	683,79±23,3[a]	< 0,040
Average diameter (cm)	3,11±2,02[a]	3,67±2,6[a]	6,57±4,3[b]	< 0,040
Average height at Lorey (m)	2,51±1,6[a]	3,26±1,8[b]	4,70±2,2[b]	< 0,021
Average basal area (m²/ha)	4,21±3,1[a]	7,2±4,6[b]	8,62±1[a]	< 0,031
Recovery (%)	19,8±58,1[a]	45,34±58,9[b]	60,75±75,1[a]	< 0,035

kP=Kouré plateau, GP=Guittodo plateau, GBCF= Gorou Bassounga classified forest

The same letters on the same line mean that there is no significant difference between the averages, while different letters mean that there is a significant difference between the averages.

Photo1: View of contracted vegetation (A=Kouré plateau, B=Guittodo plateau, C=Gorou Bassounga classified forest)

2.3 Height structure

Analysis of height class structures (Figure 3) shows that on the Kouré and Guittodo plateaux, woody vegetation is distributed in only three classes [1-3 m [, [3-5 m] and [5-7 m]. However, there is a predominance of individuals in the [1-3 m] class, followed by the [3-5 m] class and a very low representation of individuals in the [5-7 m] class, although densities are higher in Guittodo than in Kouré. The Gorou Bassounga classified forest has a more diverse distribution, with a predominance of individuals in the [3-5 m] class.

This is followed by the smallest class [1-3 m] and then the [5-7 m] class. We also note the appearance of three new classes [7-9 m [, [9-11 m [and [11-13 m [which are very poorly represented.

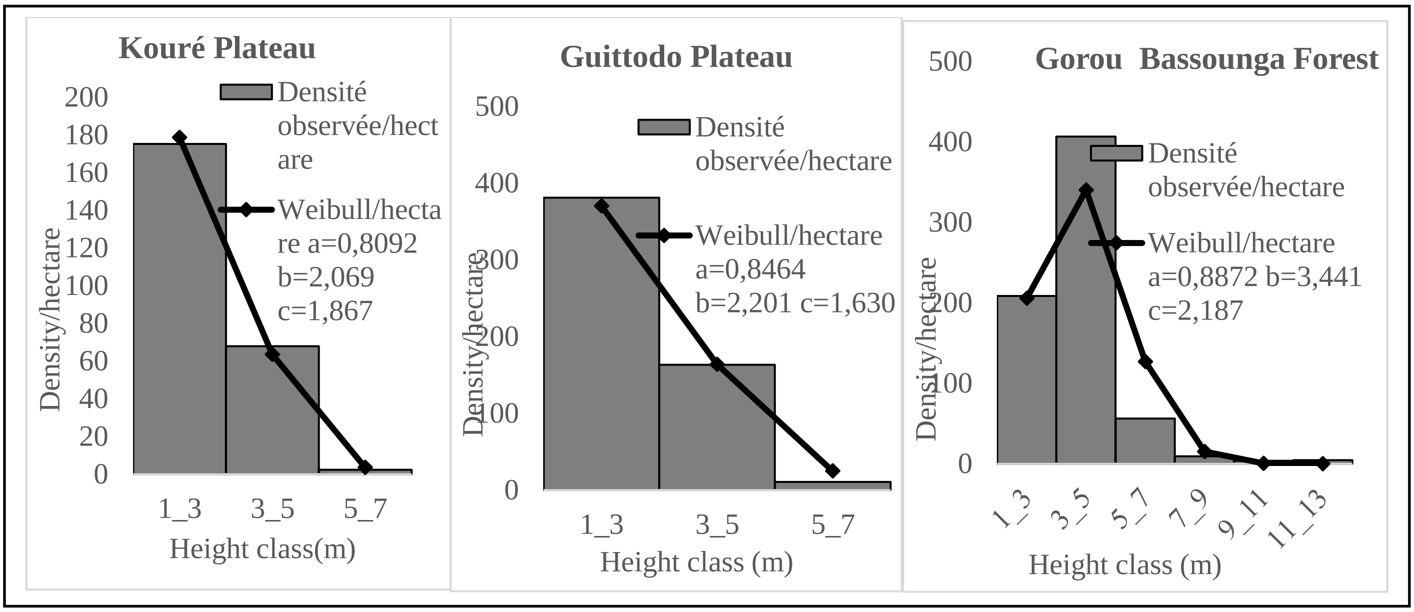

Fig.3: Height structure of the stands on the three study sites

2.4 Diameter structure

The diameter class structures of the three sites show an "inverted J" shape, with a shape parameter c of less than 1 (Figure 4). This situation is characteristic of stands with high regeneration potential. At all three sites, individuals in the [4-8cm] class predominate. This is followed by the [8-12cm] and [12-16cm] classes, with densities increasing with the rainfall gradient. The Gorou Bassounga forest is predominant, followed by the Guittodo plateau. The [16 - 20cm] class is very sparsely represented in Kouré and Guittodo. The [20 - 24cm] class is virtually unrepresented in Kouré, but is represented by rare individuals in Guittodo. The other classes [24 - 28cm [and [28 - 32cm] are represented by a few rare individuals in Guittodo.

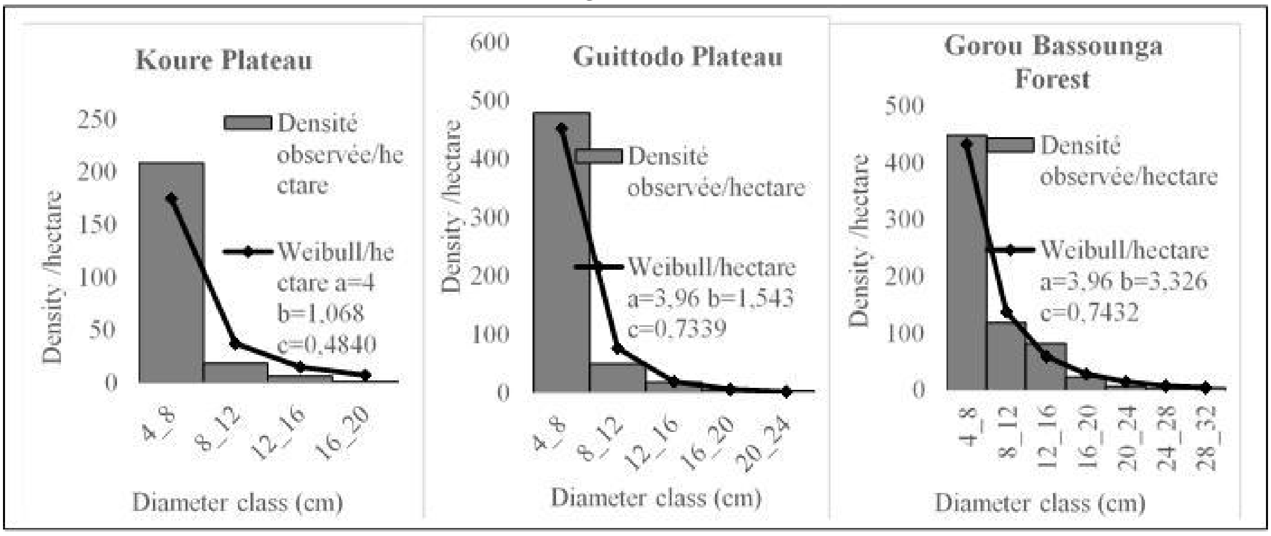

Fig.4: Diameter structure of the stands on the three study sites

2.5 Diversity indices

Analysis of the results (Table 2) shows that Shannon diversity and Pielou equitability are 2.64 bits and 0.95 respectively in the study area. Diversity is 2.37 bits on the Kouré plateau, 2.73 bits on the Guittodo plateau and 2.81 bits in the Gorou Bassounga classified forest. These values of less than 3bits indicate that the environments are of low diversity. Pielou's equitability of 0.56 at Kouré, 0.58 at

Guittodo and 0.63 at Gorou Bassounga indicates dominance in these three stands.

Table 3: Shannon diversity index and Pielou equitability

Parameter	KP	GP	GBCF	Study sites
Shannon diversity (H)	2,37	2,73	2,81	2,64
Pielou equitability (E)	0,56	0,58	0,63	0,95

The lowest similarity index (0.44) was obtained between the Kouré plateau (Sahelian zone) and the Gorou Bassounga classified forest (northern Sudanian zone) and the highest index (0.47) between the Kouré plateau and the Guittodo plateau (Sahelo-Sudanian zone).

Table 4: Sorensen indices between study sites

Sites	Koure Plateau	Guittodo Plateau	Gorou Basounga forest
Koure Plateau	1	0,47	0,44
Guittodo Plateau		1	0,46
Gorou Bassounga forest			1

2.6 Family Importance Value Index (FIV)

Analysis of the floristic characteristics showed a predominance of five families on the study sites. These are, in order of numerical importance, the Combretaceae, Caesalpiniaceae, Rubiaceae, Tiliaceae and Fabaceae families. On the Kouré plateau, the Combretaceae, Caesalpiniaceae and Mimosaceae families dominate in this order, and the Combretaceae, Mimosaceae and Fabaceae families in Guittodo. The classified forest of Gorou Bassounga is dominated by the Combretaceae family, followed by Caesalpiniaceae and Rubiaceae. However, there is a decrease in the representation of Combretaceae along a rainfall gradient and a relative presence of other species depending on the site (table4).

Table 4: Index of importance of families by site.

Family	K Plateau	G Plateau	GB forest	Study Sites
Combretaceae	292,31	287,83	243,08	261,26
Caesalpiniaceae	6,58	0,73	32,18	20,48
Rubiaceae	0,36	1,07	6,07	3,85
Tiliaceae	0,00	0,00	5,04	3,11
Fabaceae	0,00	3,38	3,50	3,05
Capparidaceae	0,00	0,34	3,01	2,01
Mimosaceae	0,75	6,65	0,41	1,97
Olacaceae	0,00	0,00	3,06	1,87
Euphorbiaceae	0,00	0,00	2,02	1,30
Anacardiaceae	0,00	0,00	1,63	1,10
Total	**300**	**300**	**300**	**300**

2.7 Species Importance Value Index (IVI)

Analysis of the results (table 5) shows that Combretum micranthum is the most represented species in the three taken together. It is followed by Combretum nigricans, Guiera senegalensis and Combretum glutinosum. In fact, on all three sites, this species has the highest index, but it decreases along the rainfall gradient. At Combretum nigricans and Combretum glutinosum, the variation in this index does not follow the rainfall gradient. The dominant IVI species ≥ 20% (Traoré et al., 2012) are Combretum micranthum, Combretum nigricans, Guiera senegalensis, Combretum glutinosum and Cassia sieberiana. The other

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species have low or zero indices. Among the latter, we can distinguish those with a zero index at one site (Acacia macrostachya and Boscia angustifolia) or at two sites (Grewia flavescens).

Table 5: Importance indices for the most represented species

E Species spèces	K Plateau de	G Plateau	GB Forest	Sites
Combretum micranthum	140,15	121,52	89,72	105,99
Combretum nigricans	50,43	100,13	86,52	82,70
Guiera senegalensis.	95,15	63,36	15,10	39,24
Combretum glutinosum	7,07	4,08	49,25	31,86
Cassia sieberiana	6,60	0,73	31,28	20,48
Gardenia Sokotensis	0,36	0,24	6,54	3,85
Grewia flavescens	0,00	0,00	5,14	3,11
Acacia macrostachya	0,00	3,38	3,49	3,05
Boscia angustifolia	0,00	0,34	3,01	2,01
Acacia ataxacantha	0,75	1,65	0,41	1,97
Total	300	300	300	300

The factorial correspondence analysis (fig. 5) used to better elucidate the interactions between the sites and the species they shelter reveals that the two axes alone concentrate 99.9% of the data, axis 1 with 81.7% and axis 2 with 18.2%. The factorial plan shows that the presence of a species is linked to the specific characteristics of each site. The Kouré plateau, which receives less water and is more anthropised, is characterised by two species, while the Guittodo plateau, in an intermediate situation, is characterised by three species. The Gorou Bassounga classified forest, located in the more watered and less developed northern Sudanian zone, stands out with eight species characteristic of the northern Sudanian climate.

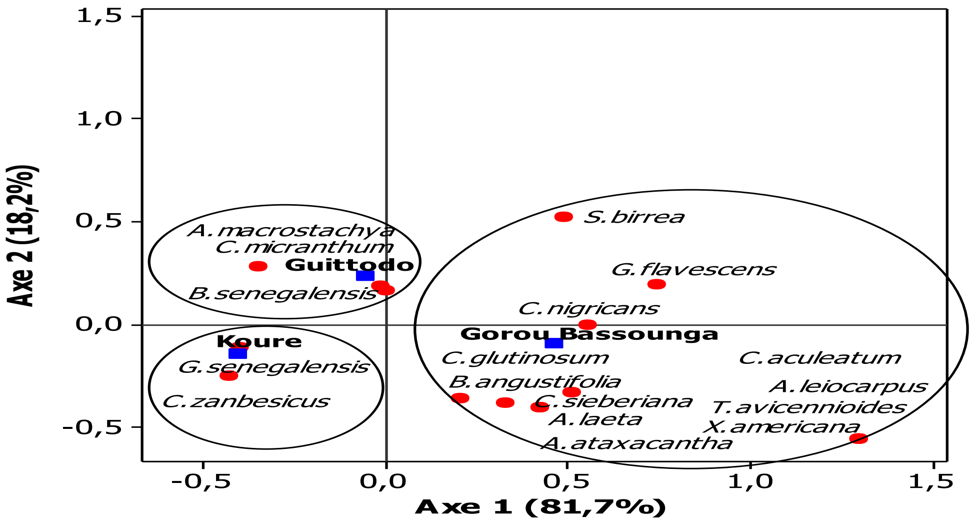

Fig.5: Distribution of characteristic species by site

IV. DISCUSSIONS

4.1 Floristic composition and vegetation structure

The results reveal that the flora of the wooded strips of contracted vegetation is rich in seventeen (17) species distributed in twelve (12) genera and nine (09) families, with a variance in mean species richness that decreases with the degree of anthropisation and increases with the rainfall gradient. According to Ngom (2013), the higher the variance of mean species richness, the greater the heterogeneity of the stand. Our results indicate the influence of human pressure on the heterogeneity of contracted plant formations. This human influence on the heterogeneity of a plant stand has also been reported by (Ngom, 2013). The rainfall regime has a positive effect on these parameters, which decrease when humans are more present. The extreme case of the Kouré plateau can be explained by the more arid climate and the massive exploitation of wood to supply the towns of Niamey and Dosso. These variations show that climate and man shape the physiognomy of this vegetation and confirm (Ambouta, 1997) who deduced that forest resources in Niger are under climatic and socio-economic pressure.

Average diameter, Lorey height, basal area and tree cover are higher in the Gorou Bassounga classified forest. This can be explained by the fact that the flora contains a few large trees with large trunks and broad crowns as a result of the low human presence and more favourable climatic conditions. These results confirm those of Akpo (1993), who reports that large trees with large crowns contribute more to tree cover and, to a certain degree, modify local ecological conditions. The cover of the Kouré plateau (19.80%) is much lower than those obtained by (Ichaou 2000) in the contracted formations of Dingazi, Kouré and Banizoumbou, which vary from 30.09% to 79.20%. On the other hand, the recoveries obtained at Guittodo (45.34%) and Gorou Bassounga (60.75%) confirm those obtained by Ichaou. In fact, basal area and cover remained low despite high densities. This can be explained by the fact that the flora is dominated by combretaceae, which are shrubs with small trunks and smaller crowns. This confirms Bouxin (1975), who maintains that there is not always a parallel between basal area, crown cover and density.

4.2 Vegetation structure

The Weibull height structure shows an asymmetrical distribution dominated by young trees, which make up the majority of the trees inventoried at the three sites. This reveals the importance of the shrub layer. The Kouré and Guittodo plateaux are dominated by the [1-3 m] class, followed by the [3-5 m] class, with very little representation of the [5-7 m] boundary class. This situation can be explained by the massive exploitation of large trees, the abrupt break in the curves of which characterises formations weakened by harvesting. Our results are more alarming than those of Ichaou (2000), who also reported the weakening of these formations due to harvesting. This shows the increasing degree of anthropisation over time. In the Gorou Bassounga classified forest, the distribution is dominated by the [3-5 m] class, followed by the [1-3 m] and [5-7 m] classes. We also note the presence of trees in the higher classes [7-9 m [, [9-11 m [and [11-13 m], which are very poorly represented, indicating a dying stand of large trees. The presence of large trees and the dominance of small and medium-sized trees give this vegetation the attributes of a more complete structure, but one that requires safeguarding. These facts are linked to a lower level of anthropisation and more favourable climatic conditions reported by (Rabiou, 2016) in the Gorou Bassounga classified forest and the W Park in Niger. The shape parameters are between 1 and 3.6, of which 1.63 at Guittodo and 2.18 at Gorou Bassounga are characteristic of stands more or less impacted by exogenous actions.

The weibull diameter structure shows inverted J distributions, similar in shape across the different sites. The highest shape parameters are observed in the Gorou Bassounga classified forest, followed by the Guittodo plateau and finally the Kouré plateau. These findings can be explained by the fact that the Kouré site is highly anthropised because of its proximity to the capital Niamey and the town of Dosso. The high demand for wood in these major towns has led to excessive logging to satisfy ever-increasing needs. The Guittodo plateau has higher densities, reflecting a lower level of human activity and more or less favourable climatic conditions. In recent years, however, the gradual establishment of camps trying to make their homes in the areas from which they fled, fleeing insecurity, has accelerated the destruction of this vegetation due to the uncontrolled exploitation of large-diameter timber. This situation highlights the link between the degradation of natural resources and insecurity, which could deal a severe blow to the structure of the vegetation if urgent measures are not taken. The case of the Gorou Bassounga classified forest reflects that of a site with little human activity, characterised by the presence of certain large-diameter trees. This situation can be explained by the low demand for firewood compared with the first two sites. As the site is in the northern Sudanian zone, the more favourable climatic conditions, combined with the low level of human activity, justify the presence of large-diameter trees. Husch et al. (2003) report that a correct interpretation of the structure of a stand requires above all a good fit between the observed shape and a theoretical distribution. The values of the shape parameter c, linked to the diameter structure on the three sites investigated, the Kouré plateau (0.4840), the Guittodo plateau (0.7339) and the Gorou Bassounga classified forest (0.7432), are less than 1. These values of less than 1 indicate an inverted J-shaped distribution, characteristic of multi-species stands in which the number of large-diameter trees is decreasing (UNDESERT, 2016). These results are similar to those obtained by (Ichaou, 2000; Rabiou, 2026), who reported the regression of large-diameter trees in the contracted formations of western Niger.

4.4 Species diversity indices and ecological importance

The Shannon diversity indices show that plant diversity is low both for the study area as a whole and at the various sites, with an increase along the rainfall gradient. This variation is linked to the adaptation of certain species to a more humid environment, to the physico-chemical properties of the soil, to the reduction in human pressure, but also to the conservation actions undertaken in the classified forest. These results corroborate those of certain authors who maintain that the variation in plant diversity between zones depends on rainfall (Neya et al., 2018; Abasse al., 2019), population density (Larwanou et al., 2012; Massaoudou et al 2015; Garba et al 2017) and edaphic conditions in these zones. The very low value on the Kouré plateau can be explained by the drier climate and the strong human presence. Pielou's equitability indices also increase with the rainfall gradient. The low values of the Pielou equitability index in the three sites indicate a phenomenon. Species from the Combretaceae family, which are characteristic of arid climates, dominate the other species and consequently colonise the environment. In the Gorou Bassounga forest, the dominance of Combreataceae is not sufficiently pronounced due to climatic and human conditions that are more favourable to the emergence of species. The value of the Sorensen index shows the existence of species common to all three sites. The similarity is stronger between the Kouré and Guittodo plateaux, which belong to the same agro-ecological zone, but with differences in annual rainfall totals. The lower similarity between the Kouré plateau and the Gorou Bassounga classified forest can be explained by their appearance in two different agro-climatic zones. The Family Importance Value Indices show that Combretaceae dominate all the areas surveyed, even in the driest zone. These results confirm (Savadogo et al., 2016), who report that droughts in the Sahel have led to a natural selection of the hardiest species, similar to that of the Combretaceae family. This means that this family is better adapted to harsh environmental conditions (Sreetheran et al., 2011). This predominance of Combretaceae has been observed by (Ouédraogo, 2006, Bognounou et al., 2009, Froumsia et al., 2012) who found similar results respectively in western Burkina Faso in the sectors (northern Sahelian, southern Sahelian, northern Sudanian and southern Sudanian) and in the Kalfou forest reserve in Cameroon. The decrease in the frequency of Combretaceae with the rainfall gradient can be explained by the xerophytic nature of the species, as reported by Aubreville (1950). Other authors (Rabiou, 2016; Abasse et al., 2019) link the decrease in the proportion of Combretaceae from the strict Sahelian zone to the northern Sudanian zone to rainfall. They are indicative of a dry climate (Rabiou, 2016) and can extend their roots as far as the water table to satisfy their water needs (Abdourhamane et al. 2013). The low representation or absence of certain families on certain sites is justified by their low capacity to adapt or not to the local conditions characteristic of these sites. Correspondence factorial analysis revealed Guiera senegalensis and Croton Zambeisicus as characteristic species of the Kouré plateau, Acacia macrostachya, Combrethum micrathum and Bossia senegalensis for the Guittodo plateau and eight species for the Gorou Bssounga classified forest. This reflects the greater presence of these species on the latter site, where local conditions (climate, soil and human pressure) are more favourable. (Ambouta, 1997 and Ngom, 2013) describe these characteristic species as good indicators of changes in the state of woody vegetation. Our results confirm those of Aubreville (1950), who reports that the distribution of woody species is strongly conditioned by their xerophilic or hygrophilic characteristics, and those of Charahabil (2013), who also links it to anthropogenic pressure. In this context, many woody species are regressing in favour of a few more resilient species.

V. CONCLUSION

This study shows that the floristic composition and structure of contracted vegetation are dependent on both rainfall and human pressure. They evolve along the North-South rainfall gradient and decline with the level of human activity. The Kouré and Guittodo plateaux are characterised by a stand dominated by small and medium-diameter shrubs. Large-diameter trees are absent from Kouré and are very poorly represented on the Guittodo plateau. This is an indicator of a growing human presence. In the Gorou Bassounga forest, there are a few large-diameter trees, indicating a less pronounced level of human activity. Combretaceae predominate on all the sites investigated, with proportions decreasing with the rainfall gradient. Statistical analysis of dendrometric parameters shows significant differences along this gradient. The results of this research contribute to a better understanding of the current state of the floristic composition and structure of this characteristic vegetation of western Niger, with a view to better preserving the species that are subject to strong climatic and human pressures.

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Climate change and sustainable management of agro-pastoral dams in the department of ouangolo: From water scarcity to inter-community tensions

Changement climatique et gestion durable des barrages agropastoraux dans le departement de ouangolo : De la rarete des ressources en eau aux tensions intercommunautaires

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Abstract— *Climate change is currently posing a challenge to social cohesion in rural communities in Côte d'Ivoire, given the social upheavals it has caused. In Ouangolo, for example, the perfect cohabitation between Fulani herders and indigenous farmers is gradually being called into question by the adverse effects of climate change. The small hydraulic dams are drying up, creating social divisions as a result of conflicts of interest over their control. It is this issue that this study addresses. It is based on a qualitative approach and requires the use of Alain Touraine's sociological action theory. In the end, it emerged that climate change has led to a reduction in Ouangolo's water resources, to the point where the last water points are now the subject of covetousness between the local farmers and Fulani herders. Each party wants to preserve its access to water resources. The Peulhs, observing the partial or total occupation of the grazing and ox-grazing areas around the dams that they own, make the animals cross into the cultivated areas, destroying everything in their path. This does not leave the locals indifferent. They express their indignation. So, in a context where these watering holes have become an existential issue for these populations, there is a risk of major confrontation over control of the water. In Ouangolo, conflict is a recurring phenomenon between these two players.*

Keywords— ***Climate change, Agropastoralism, Peulh, Water, Inter-community tensions***

Résumé— *Le changement climatique représente aujourd'hui un défi pour la cohésion sociale dans les communautés rurales de la Côte d'Ivoire, au vu des bouleversements sociaux qu'il a engendré. A Ouangolo par exemple, la parfaite cohabitation entre éleveurs peulhs et autochtones agriculteurs est progressivement remise en cause en raison des effets néfastes du changement climatique. Les petits barrages hydrauliques s'assèchent et crées des fractures sociales du fait des conflits d'intérêt pour leur contrôle. C'est à cette problématique que s'intéresse cette étude. Pour ce faire, elle s'est appuyée sur une approche qualitative et a nécessité l'usage de la théorie de l'actionnalisme sociologique d'Alain Touraine. A termes, il ressort que* *le changement climatique a entrainé la réduction des ressources hydrauliques de Ouangolo au point où les derniers points d'eau sont aujourd'hui sujets à convoitise entre autochtones agriculteurs et éleveurs peulhs. Chaque acteur entend préserver son accès aux ressources hydrauliques. Les Peulhs, observant l'occupation partielle ou totale des espaces de pâturage et de passage des bœufs autours des barrages dont ils en sont propriétaires, font traverser les animaux dans les espaces de culture qui détruisent tout sur leur passage. Ce qui ne laisse pas les autochtones indifférents. Lesquels manifestent leur indignation. Ainsi, dans un contexte où ces points d'eaux sont devenus un enjeu existentiel pour ces populations, il y a un risque d'affrontement majeur pour le contrôle de l'eau. Surtout qu'à Ouangolo, le conflit est un phénomène récurrent chez ces deux acteurs.*

***Motsclés*— Changement climatique, agropastoralisme, Peulh, eau, tensions intercommunautaires**

I. INTRODUCTION

Depuis le XXème siècle, l'on s'interroge sur les impacts réels des activités humaines sur le climat. Un problème de plus en plus préoccupant, surtout, avec les bouleversements climatiques constatés ces dernières décennies. En fait, le climat se réchauffe en causant des dommages sur les activités humaines du fait de l'émission des gaz à effet de serre dans l'atmosphère terrestre. Le réchauffement climatique est aujourd'hui en hausse de 1.1°C par rapport à l'ère préindustrielle (Mellinger, Sachs et Gallup, 2000). Comme effets manifeste de ce phénomène, il est à l'origine de la fonte des glaciers et par ricochet de la hausse du niveau des mers et des océans, de la désertification et du déséquilibre pluviométrique (Guivarch et Taconet, 2020). Ces conséquences sont observables à l'échelle planétaire et impactent notamment les pays de l'Afrique de l'Ouest. D'autant qu'ils sont soumis à des épisodes climatiques secs et pluvieux ponctués de saisons sèches dont l'intensité et l'extension spatiale sont généralement démesurées et imprévisibles (Kouassi *et al.*, 2017 cités par Kouassi, Kouao et Kouakou, 2022).

Le contexte ivoirien illustre bien cet état de fait. En effet, le pays a enregistré depuis les années 60 des ruptures pluviométriques avec des conséquences non négligeables sur les activités agricoles. Entre 1966 et 2000, le changement climatique a provoqué des déficits pluviométriques de l'ordre de 21% avec une hausse thermométrique comprise entre +1 et +1.6°C (Danumah, 2016 ; Brou, Akindès et Bigot, 2005). Sur la période comprise entre 1981 et 2010, la température moyenne était de 26.2°C contre 27°C pour l'année 2020 et 27.3°C pour l'année 2021. Selon la SODEXAM, le climat ivoirien se réchauffe au fil des ans. L'année 2021 a été la plus chaude depuis 1961.[1] Cette hausse continuelle du climat est un obstacle pour le développement national. D'autant plus que l'économie ivoirienne est essentiellement basée sur l'agriculture. En effet, comme le dit Hansen (2002), le climat a une forte influence sur l'agriculture. Aucune activité agricole ne peut prospérer sans des conditions climatiques favorables. C'est pour quoi, vue les aléas climatiques, les populations rurales du pays, particulièrement celles du Nord, sont confrontées à des saisons sèches de plus en plus longues suscitant de vives inquiétudes. En fait, elles peinent à rentabiliser leurs productions et les terres agraires commencent à se raréfier en raison de l'aridification du sol.

Ainsi, les ressources naturelles encore disponibles sont soumises à une forte pression. Elles sont devenues sujet de convoitise. Chaque communauté ou individu cherche à s'en approprier. Dans le Département de Ouangolo par exemple, l'aridité des terres et l'évaporation des eaux de surface ont engendrées une situation conflictuelle entre agriculteurs autochtones et éleveurs peulhs pour le contrôle des barrages hydrauliques. Si dans d'autres localités, les autochtones ont le monopole sur les points d'eau, dans le Département de Ouangolo, il existe deux types de barrages dont l'un appartient aux autochtones et l'autre aux éleveurs peulhs. Pour les uns, ces barrages sont des endroits propices pour les activités maraichères et pour les autres, ce sont plutôt des espaces favorables au développement pastoralisme. En outre, avec le réchauffement climatique, la plupart des barrages des autochtones se sont asséchés amenant les autochtones à se tourner vers les barrages des éleveurs peulhs pour la pratique des activités maraichères. Cependant, avec l'intensification de l'agriculture autour de ces points d'eau, l'association agriculture-élevage devient de plus en plus conflictuelle. Ainsi, l'on constate une dégradation progressive des rapports sociaux entre ces deux groupes d'acteurs distincts.

Comment le changement climatique a-t-il conduit à la dégradation des rapports sociaux entre agriculteurs autochtones et éleveurs peulhs dans le Département de Ouangolo ? Quel est le contexte de réalisation des petits barrages agropastoraux dans le Département de Ouangolo ?

[1] https://www.scidev.net/afrique-sud-saharienne/news/cote-divoire-2021-aura-ete-lannee-la-plus-chaude-depuis-61-ans/

En quoi le changement climatique a-t-il bouleversé les jeux d'acteurs autour des petits barrages agropastoraux dans le Département de Ouangolo ? En quoi a-t-il provoqué la dégradation des rapports sociaux entre agriculteurs et éleveurs peulhs dans le Département de Ouangolo ?

II. CADRE THEORIQUE DE L'ETUDE

L'actionnalisme sociologique d'Alain Touraine est celle mobilisée dans cette étude. Cette théorie met l'acteur au centre de sa lecture du social. L'acteur est porteur de projet et se bat pour imposer un ordre différent des choses et des situations. Son but est d'établir un ordre soumis à sa volonté, à ses intérêts. La sphère sociale est le théâtre d'un jeu de tensions ou de conflits d'intérêt (N'Da, 2015). Ainsi, avec la réduction des ressources naturelles en eau dans le Département de Ouangolo, la course pour le contrôle des barrages agropastoraux a favorisé l'émergence des tensions d'intérêts entre Peulh et autochtones. Un jeu d'acteur dans lequel chaque groupe lutte pour imposer sa position et sa place dans les périphéries des basfonds pour la bonne conduite de ses activités.

III. MATERIELS ET METHODES

Cette étude s'inscrit dans une approche qualitative. La méthodologie de collecte des données a fait intervenir la recherche documentaire, l'entretien semi directif et le focus group. La documentation a porté sur la consultation d'articles, de rapports et divers publications scientifiques en ligne, sur l'emprunt carbone de l'humanité, le réchauffement climatique et ses conséquences particulièrement sur la réduction de la pluviométrie. Les entretiens semis directifs ont été structurés autours du contexte de réalisation ainsi que des stratégies de gestion des barrages agropastoraux dans le Département de Ouangolo. Il a aussi traité de la manière dont le changement climatique a fait des éleveurs peulhs les principaux détenteurs et gestionnaires des barrages agropastoraux de la zone. Dans ce même contexte, d'autres questions ont également porté sur la manière dont, dans un contexte de changement climatique, ce monopole a conduit à la dégradation des rapports sociaux entre les éleveurs peulhs et leurs tuteurs sociaux.

Les acteurs concernés par les entretiens sont les leaders et chefs familles d'éleveurs peulhs et les productrices de vivrier de Ouangolo. Un focus groups a également été réalisé auprès des autorités coutumières de cette localité. Au total, un échantillon de six (6) chefs de leaders et chefs de familles d'éleveurs peulhs et 15 productrices de vivrier ont été enquêtés. Le focus a enregistré la participation de trois (3) membres de la chefferie de Ouangolo dont le chef et deux de ses notables. La technique d'échantillonnage utilisée est le choix raisonné et le quota des productrices de vivrier a été atteint sur la base de la saturation. Quant au nombre de Peulhs enquêtés, l'échantillon de six (6) a été atteint sur la base du volontariat d'autant plus que la plupart des Peulhs rencontrés n'ont pas voulu participer à l'étude. Dans l'ensemble, l'échantillon de cette étude est composé de 24 personnes.

La collecte des données a nécessité l'usage de magnétophones pour l'enregistrement des entretiens et le focus groups dont la plupart ont été réalisés en Malinké ou en senoufo. Ces enregistrements ont été traduits et retranscrit en Français avant d'être dépouillés.

Le dépouillement des données s'est fait de façon manuelle sur la base de l'analyse de contenue qualitative. Elle a consisté au traitement des données collectées de manière inductive. Ce travail a permis d'établir les liens existants entre les variables convoquées. A termes, il a été possible de déterminer le rapport existant entre changement climatique et dégradation des liens sociaux entre les Peulhs de Ouangolo et leurs tuteurs sociaux.

IV. RESULTATS

4.1 Contexte de réalisation des barrages agropastoraux

L'élevage est la principale activité économique des Peulhs. Il leur fournit richesse et nourriture. C'est pour mener à bien cette activité dont sa poursuite dans le Sahara devenait de plus en plus difficile en raison du réchauffement climatique et de l'avancée du désert que des Peulhs ont migré en Côte D'Ivoire. Un territoire qui dispose de points d'eau et de pâturage donc propice au développement du pastoralisme.

Selon Diallo (1995), la présence des éleveurs peulhs dans le pays tire aussi ses origines des politiques de développement de l'élevage du bovin avec la création de la SODEPRA en 1970. Dans le cadre de ses activités, cette structure a en effet mis en place des stratégies de prise en charge médicale des bœufs et de formation des éleveurs. Les Peulhs ont perçu cela comme un mobile pour leur migration dans le pays. Puisque les bœufs étaient mieux traités et nourris en Côte d'Ivoire que dans leur pays d'origine. De plus, avec la mise en place des couloirs de transhumance, les Peulhs avaient une facilité à faire paitre leurs animaux sans heurt. Et l'Etat a même encouragé la sédentarisation des Peulhs déjà présents en Côte d'Ivoire.

Le Département de Ouangolo est l'une des localités identifiées par les Peulhs comme propice à la pratique de l'élevage. Les agriculteurs locaux ont profité de la présence des Peulhs pour leur confier des bœufs dont ils seraient propriétaires. Ils ont alors jugé nécessaire de les intégrer d'autant plus qu'ils occupaient une fonction d'intérêt commun (Diallo, op. cit.). Une fonction qui permettait aux autochtones de non seulement disposer de bétails nécessaires à la pratique de la culture d'attelage mais aussi d'enrichir les terres agraires à travers l'usage des bouses dans les champs en guise de fertilisant. Les Peulhs ont ainsi obtenu des autochtones, l'autorisation de s'installer sur leur territoire et bénéficier des ressources pastorales locales. Ils ont entrepris la construction de petits barrages hydrauliques. Le principal objectif pour eux était d'accroitre les ressources pastorales disponibles. De sorte à ce qu'ils aient de quoi nourrir leurs animaux tout au long de l'année et même pendant les saisons sèches. Puisqu'avec les vagues de sécheresse constatées notamment dans le nord ivoirien depuis la deuxième moitié du XXème siècle, l'alimentation et l'abreuvage des animaux en période de sècheresse sont devenus problématiques.

Ces barrages ont aussi des avantages pour les autochtones. Ils les utilisent pour leurs activités agricoles. C'est d'ailleurs pour renforcer leur accès et accroitre leurs capacités de production qu'ils ont eux aussi construit des barrages. Ainsi, dans le Département de Ouangolo, on distingue deux types de barrages, à savoir ceux réalisés par les autochtones et ceux appartenant aux Peulhs.

Si les Peulhs ont pu construire des barrages, c'est aussi parce que leur intégration aux communautés tuteures, leur a donné un accès au foncier local. Même s'ils ne peuvent pas prétendre au titre de propriétaire foncier, face à la nécessité de répondre aux besoins de plus en plus croissants en eau, l'autorisation leur a été donnée par les autochtones pour la réalisation de petits barrages hydrauliques. Selon, une autorité coutumière de Ouangolo, la plupart des barrages agropastoraux de la zone appartiennent aux Peulhs. Ce qui traduit le bon niveau d'intégration de la communauté peulh de Ouangolo.

> *Les Peulh sont bien intégrés et même plus favorisés que les autochtones eux-mêmes puisque la plupart des barrages les appartiennent.»* **Déclare une responsable d'une association des femmes de cette localité**.

Cet état de fait s'explique aussi par le fait que ces éleveurs disposent généralement de plus de ressources économiques que les agriculteurs locaux. De plus, ils vivent au sein d'organisations d'éleveurs professionnellement mieux organisées, structurées et plus économiquement stables que celles de leurs hôtes. Ainsi, lorsqu'il s'est agi de faire face au déficit en eau, ces éleveurs ont eu une meilleure marge de manœuvre par rapport à leurs tuteurs sociaux.

Comme mode de gestion des points d'eaux, chaque communauté se charge de gérer ses barrages. Mais dans l'usage, quel que soit le propriétaire d'un barrage, il est aussi bien utilisé par les autochtones que par les Peulhs. Afin d'éviter d'éventuels conflits d'intérêt entre agriculteurs autochtones et éleveurs peulhs, des pistes et zones pastorales ont été dégagées aux alentours des barrages afin de permettre aux bœufs de paitre et s'abreuver. Et s'il arrivait que des tensions éclataient, à la suite de la destruction de cultures par des bœufs, une commission de crise dirigée par les autorités coutumières est mise en place afin d'éviter toutes confrontations directes. Cela passe par le dédommagement de la victime. Cependant, avec le changement climatique, cet ordre social subit progressivement des bouleversements. Lesquels provoquant parfois de vives tensions intercommunautaires.

4.2 Changement climatique et jeux d'acteurs autours des petits barrages agropastoraux

A l'instar de l'ensemble du territoire ivoirien, le Département de Ouangolo subit les effets néfastes du changement climatique. Les conséquences de ce phénomène se manifestent notamment par l'acidification et l'aridification des terres, des retards de pluies et des saisons sèches de plus en plus longues. Les saisons sèches qui s'étendaient généralement du mois de Novembre à celui de Mars voire mi-avril couvrent aujourd'hui une période allant d'Octobre à Mai voire Juin. Aujourd'hui, même si de rares pluies sont signalées par endroit durant la saison sèche, son irrégularité est telle que pendant cette période, en dehors des périphéries des basfonds non asséchés et des petits barrages hydrauliques encore fonctionnels, presqu'aucune activité agricole n'est possible.

> *Pendant la sécheresse, les terres deviennent trop dures et on ne peut plus rien planter. Parfois, les basfonds deviennent tellement secs que plus rien ne peut pousser. Il peut même arriver que les puits creusés dans les basfonds pour l'arrosage des cultures s'assèchent aussi.* ***Explique une productrice de vivrier.***

Le secteur de l'élevage est aussi touché par les effets néfastes de la sécheresse surtout avec les pics de chaleur, la réduction des airs de pâturage et d'abreuvage des bœufs.

> *Lorsqu'il ne pleut plus, ce n'est vraiment pas facile de nourrir les animaux. Toutes les herbes deviennent sèches. Dans la brousse, nous sommes obligés d'envoyer les animaux dans les endroits situés à proximité des*

> *points d'eau puisque c'est là-bas seulement qu'on peut avoir de l'herbe fraîche pour eux et de l'eau. Si tu ne fais pas ça tes bœufs seront malades ou ils vont mourir de faim. Ils ne peuvent pas manger que de l'herbe sèche à tout moment. (**Propos d'un leader communautaire peulh**).*

La crise climatique a ainsi provoqué une concentration de l'activité agropastorale dans les périphéries des basfonds et petits barrages hydrauliques. Si les points d'eau appartenant aussi bien aux autochtones qu'aux Peulhs sont utilisés pour les activités agricoles et pastorales, la pression de l'activité agricole demeure importante. Cette pression est telle que certains basfonds et barrages ont tari particulièrement ceux appartenant aux autochtones du fait de la forte concentration des activités agricoles.

> *La plupart des barrages encore fonctionnels qui sont ici à Ouangolo appartiennent aux Peulhs.* **Avance la responsable d'une coopérative de vivrier.**

En fait, avec le réchauffement de la planète, ces points d'eau n'arrivent pas à régénérer la quantité d'eau absorbée par les activités humaines et l'évaporation. Ce qui a engendré un renforcement de l'agriculture en périphéries des petits basfonds peulhs jusqu'à une époque récente, peu utilisée pour l'activité agricole. D'autant plus qu'ils sont devenus les principaux points d'eaux encore disponibles.

> *Les barrages des peulhs là sont les seuls endroits où nous pouvons cultiver pendant la saison sèche. Nous n'avons pas le choix c'est pourquoi la plupart des femmes vont faire leur champ au bord des barrages peulhs. Si tu ne le fait pas, comment vas-tu nourrir ta famille ? **S'interroge une productrice de vivrier.***

La pression est devenue telle que les espaces et pistes autrefois dégagés par les Peulhs pour l'alimentation et l'abreuvage des animaux sont progressivement transformés en superficies agricoles. Cet état de fait ne se fait pas sans heurt. Puisque les Peulhs s'y opposent fortement. En tant que propriétaires de ces points d'eau, ils exigent leur droit d'accès aux barrages. Des appels qui ne produisent pas toujours les effets escomptés.

4.3 De la convoitise des petits barrages agropastoraux à la dégradation des rapports sociaux entre agriculteurs et éleveurs peulhs à Ouangolo

La concentration des activités agropastorales aux alentours des barrages hydrauliques dont les éleveurs peulhs en sont propriétaires a eu pour conséquence le bouleversement de l'ordre socio-relationnel existant entre Peulhs et autochtones. Du statut, d'étranger, d'éleveur nomade, le Peulh est devenu sédentaire et du sédentarisme au propriétaire de petits barrages hydrauliques dont sont devenus dépendant les autochtones surtout en période de sécheresse. Cette nouvelle configuration de l'environnement sociale a entrainé la montée des tensions entre ces deux groupes sociaux avec pour centre d'intérêt l'accès et le contrôle des points d'eaux. Les autochtones, par leur titre de propriétaire terrien et tuteur des Peulhs, réclament un droit d'accès permanant et illimité aux barrages peulhs. Et les Peulhs, par leur titre de propriétaires revendiques et exigent la réduction des activités agricoles dans les périphéries des barrages.

> *Bien vrai que les barrages sont à eux, nous avons as de problème avec cela, mais ils sont chez nous, ils doivent donc nous permettre d'en profiter aussi non !* **S'exclame une productrice de vivrier**

> *Nous ne pouvons pas les laisser occuper tous les espaces autours de nos barrages. Parce que si cela continu comme ça, finalement ces barrages n'existeront plus. Ces barrages sont à nous, nous devons donc les protéger et permettre à nos bœufs de boire de l'eau et se nourrir.* **(Propos d'un éleveur peulh)**

Si les barrages hydrauliques représentent tant d'intérêt pour ces derniers, c'est aussi parce qu'ils constituent, pour les Peulhs, l'ultime moyen pour mener à bien leur élevage. Une activité qui constitue le fondement de leur culture et activités socioéconomiques. Et du point de vu des autochtones, même si certains d'entre eux sont des éleveurs, les barrages conditionnent avant tout, l'approvisionnement des familles en produits maraichers, l'une de leur principale source de revenu. Ainsi, les petits barrages hydrauliques constituent un enjeu d'intérêt majeur pour chacune de ces communautés. Ce conflit d'intérêt a engendré une lutte pour l'accès à ces points d'eau.

Chaque communauté use de stratégies protectionnistes pour la préservation de ses intérêts. Les autochtones utilisent leur statut de tuteur pour renforcer leur accès aux barrages afin de garantir de façon quantitative leur production. Cet accroissement des activités agricoles n'est pas sans conséquences. Puisqu'il se fait au détriment de l'élevage par la perte de prairie et de pistes d'accès aux barrages.

> *Nous savons que nous sommes étrangers ici. Même si les basfonds ont été réalisés par nous et nous appartiennent, nous ne pouvons pas leur interdire de travailler leurs champs. C'est pourquoi nous leur avons dit qu'ils peuvent bien vrai travailler, mais qu'ils nous laissent de l'espace aux alentours des basfonds afin que nous pussions faire paitre et boire nos bœufs. Mais comme, avec la sécheresse là, ce sont seulement nos barrages qui contiennent de l'eau actuellement, tous les agriculteurs qui travaillaient dans les autres basfonds ou barrages sont venus s'ajouter à ceux qui travaillaient déjà aux abords de nos barrages. Tellement ils sont devenus nombreux, l'espace que nous leur avons donné ne suffit plus. Ils ont donc progressivement occupé tous les espaces. Autour de certains barrages, il n'y a plus de pairie et même pour aller faire boire les animaux, c'est un problème.* **Explique un leader communautaire peulh de Ouangolo.**

Les propos de cet enquêté mettent en relief le conflit d'intérêt qui prévaut autour des petits barrages agropastoraux de Ouangolo. Le problème est qu'il provoque une rupture relationnelle, par ricochet, une dégradation des rapports sociaux entre groupes antagonistes. Jusque-là les éleveurs peulhs et leurs tuteurs sociaux réussissent à cohabiter sans de véritable heurt et les conflits sont généralement étouffés par la médiation locale. Cependant, avec le réchauffement climatique qui devient de plus en plus préoccupant, la situation risque d'évoluer. Surtout qu'actuellement des cas d'accidents sont fréquemment enregistrés. En effet, pour faire face au difficile accès des bœufs aux barrages hydrauliques, les éleveurs font passer, parfois, les bœufs dans les champs des agriculteurs détruisant sur leur passage les cultures.

> *Vous saviez, c'est une situation qui nous préoccupe beaucoup. Après le passage des bœufs, ce sont des mois ou des semaines de travail qui sont perdu. Qui va nous rembourser nos investissements et nos efforts personnels ? Puisque ce n'est pas toujours qu'on nous dédommage. Si le propriétaire des bœufs n'est identifié, les dommages ne sont pas remboursés. Beaucoup de champs sont détruits par les bœufs sans qu'on ne soit en mesure d'identifier les coupables. C'est un véritable problème ici.* **Explique une femme, leader d'une coopérative de vivrier de Ouangolo.**

Ces frustrations sont de potentiels facteurs de conflit. Puisque pour les producteurs, la destruction des cultures est un facteur de dégradation des conditions de vie. Une situation difficilement supportable pour ces derniers. Il l'accepte donc avec assez de retenu.

> *C'est mon jardin que j'entretien au barrage-là qui me donne à manger et qui me permet d'aider mon mari à scolariser nos enfants. Donc c'est difficile d'arriver au barrage et constater que les bœufs ont détruit mon champ. Il y a même des femmes parmi nous qui sont veuves avec des enfants, d'autres célibataires avec des enfants aussi, elles vivent des produits de leur jardin. Donc lorsque nous retrouvons nos champs dévastés par les bœufs sans pouvoir identifier ni les animaux, ni leur propriétaire, ça fait mal. Si rien n'est fait pour nous aider à protéger nos champs, on sera obligé nous-même de défendre nos intérêts.* **Explique une productrice de produit maraicher.**

Les effets néfastes du changement climatique constituent ainsi est un problème majeur pour le maintien de la cohésion sociale entre agriculteurs et éleveurs dans le Département de Ouangolo. Avec l'intensification des impacts du réchauffement climatique sur les réserves en eaux, la course intercommunautaire pour le contrôle de cette ressource risque de muer en confrontation directe surtout que des cas conflits Peuhls-agriculteurs mais à petit échelle ont souvent été enregistrés dans la zone. Un cas de conflit a été rapporté par une productrice comme suit :

> *En 2020, un peulh a découpé un autochtone dans la brousse parce qu'il tentait d'empêcher les bœufs du peulh de saccager son champ… Les jeunes étaient très révoltés, ils voulaient entrer dans le campement peulh pour tout bruler.*

Le risque d'un conflit est d'autant accrue dans la mesure les données de l'enquête ont montré que les autorités coutumières sont retissant, lorsqu'il s'agit de traiter les cas de litiges opposant les agriculteurs locaux aux éleveurs peulhs pour l'accès et l'usage des points d'eau dont ces derniers en sont propriétaires.

V. DISCUSSION

Les résultats de cette contribution ont dans un premier temps exposé le contexte du flux migratoire des éleveurs peulhs en Côte d'Ivoire. En effet, depuis le XXème siècle, la baisse drastique de la pluviométrie dans la zone sahélienne a engendré l'aridification des terres et la raréfaction des ressources pastorales. De ce fait, les éleveurs notamment les Peulhs des Etats de la zone ont entamé un phénomène migratoire vers les pays situés au Sud du sahel. En Côte D'Ivoire, ils se sont entre autres installés dans le Département de Ouangolo ou ils ont bénéficié d'une intégration à la communauté autochtone. Surtout que ces derniers leur confiaient les bœufs dont ils sont propriétaires et les animaux servaient également à la pratique de la culture d'attelage et la bouse utilisée comme fertilisant. Cela transparait dans l'article d'Ancey (1997) lorsqu'elle a fait savoir que l'immigration des éleveurs peulhs dans le nord de la Côte D'Ivoire remonte à l'époque coloniale. Diverses crises sociales ont provoqué la modification des parcours pastoraux dans les régions sahélo-sahéliennes et poussé certaines familles d'éleveurs peulhs à migrer vers le sud. Plus tard, les années de sécheresse ont amplifié ces flux. Un flux favorisé aussi par les investissements considérables en infrastructure et en suivi sanitaire mis en œuvre à l'époque. Diallo (1995) s'inscrit dans la même logique lorsqu'il avance également que l'arrivée et l'installation des Peulhs sur le territoire ivoirien est une politique voulue par l'Etat de Côte D'Ivoire pour réduire le top d'importation en ressources bovines du pays. Les travaux de Bernardet (1986) ont également corroboré aussi le résultat susmentionné. Ils ont mis en exergue les avantages tirés par les communautés locales de la présence des Peulhs. En fait, selon lui, les autochtones confiaient des bœufs en élevage dont ils en sont propriétaires aux Peulhs. Ces derniers étaient rémunérés par mois. Vue ces centres d'intérêts communs, il est donné de constater, dans la présente étude que les Peulhs sédentaires de Ouangolo ont bénéficié d'une intégration à la communauté locale. Ce qui leur a permis d'avoir accès à la terre. Un accès qui leur a permis d'entreprendre des projets de construction de petits barrages hydrauliques agropastoraux. Toutefois, il existe aussi des petits barrages appartenant aux locaux. L'étude de Soro (2021) réalisée à Tienko relate certains éléments de ce résultat. En effet, dans sa zone d'étude, les peulhs sédentaires ont également accès au foncier. Mais, leur usage de la terre se limite à la production de vivriers. La plupart de cette production est destinée à leur consommation familiale. A Ouangolo où cette étude a été réalisée, les points d'eau réalisés par les Peulhs étaient dans un premier temps faiblement utilisé par les autochtones pour les activités agricoles. Mais avec le réchauffement climatique, la plupart des barrages appartenant aux autochtones ont tari. Cela a eu pour conséquence le renforcement de la production agricole en périphérie des barrages peulhs. En fait, si autrefois les Peulhs avaient une facilité d'user de leurs barrages sans heurt, aujourd'hui, le changement climatique a changé la donne. Il y a une intensification de l'activité agropastorale. Une situation qui provoque souvent des tensions intercommunautaires. En fait, les accès des animaux aux points d'eau ont progressivement été occupés par les agriculteurs locaux. De ce fait, le passage des bœufs dans les périphéries des barrages jusqu'aux points d'eau est souvent accompagné de destruction de cultures agricoles. Hellendorff (2012) traite de faits similaires lorsqu'il avance l'idée selon laquelle le changement climatique a entrainé une pression autour des ressources agropastorales de sa zone d'étude : le Sahel. En effet, cette pression a suscité des conflits d'intérêt qui ont à leur tour détérioré les rapports intercommunautaires entre éleveurs et agriculteur. Outre cela, une autre étude, à savoir celle de Bernardet (1986) souligne en partie les mêmes faits. Elle a en effet mis l'accent sur la destruction des produits agricoles par les bœufs. Selon cet auteur, en cas de destruction des cultures, les victimes étaient dédommagées. Mais dans le cas de Ouagolo, aujourd'hui les victimes de destructions de cultures ne sont pas tous dédommagées car les coupables ne sont pas toujours retrouvés. Aussi, en raison du fait que ces barrages en question appartiennent au Peulhs, ces derniers estiment avoir le droit de faire paitre leurs animaux. Alors, en cas d'intrusion des bœufs dans les champs, ils ne se sentent pas toujours dans l'obligation de dédommager les victimes provoquant ainsi des frustrations et des tensions intercommunautaires. Or, dans le cas de l'étude de Bernardet (Op. cit), le fait que les ressources agropastorales appartiennent aux locaux obligeait ces éleveurs à dédommager leurs victimes.

VI. CONCLUSION

Dans le contexte actuel de changement climatique, la course aux ressources constitue un problème social. A Ouangolo, cela se manifeste notamment autour des petits barrages agropastoraux. Dans cette localité, il existe deux types de barrages hydrauliques. D'un côté il y a ceux appartenant aux autochtones et de l'autre ceux des Peulhs. Les petits barrages des peulhs sont les plus nombreux et les moins utilisés par rapport à ceux des autochtones. Mais avec le réchauffement climatique, certains des petits barrages hydrauliques surtout ceux appartenant aux locaux ont tari en raison de la forte concentration de l'activité agricole qui ne permet pas à ces points d'eau de se régénérer. Ce qui a entrainé un renforcement de l'activité agricole dans les périphéries des petits barrages hydrauliques des Peulhs. Au point où ces derniers peinent à se frayer un chemin jusqu'aux points d'eau sans causer de dommages aux plantes des agriculteurs autochtones. La situation devient conflictuelle dans la mesure où chaque communauté se bat pour garantir son accès aux points d'eau. Les Peulhs, par leur titre de propriétaires des points d'eau réclament un accès permanant. Les autochtones, par leur droit de propriétaires fonciers revendiquent leur accès aux barrages. Ces jeux d'intérêt creusent de plus en plus les écarts relationnels entre Peulhs et hôtes. Cela risque d'engendrer des conflits sociaux entre agriculteurs et éleveurs majeurs surtout avec le réchauffement graduel de la température terrestre qui ne cesse de s'intensifier. Toutefois, l'échantillon assez restreint de cette étude ne permet pas évaluer ce problème à grand échelle ni d'identifier les localités rurales de la zone ou le risque de conflit pour le contrôle de l'eau serait plus élevé dans le Département de Ouangolo. Une recherche approfondie de l'impact du réchauffement climatique sur les ressources en eau encore disponibles dans cette partie de la Côte d'Ivoire serait également nécessaire.

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Evaluation of Natural Suitability of Human Settlements Environment in Hangzhou Based on GIS

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***Abstract*— *Taking Hangzhou City as the study area, Geographic Information System (GIS) technology was used, selecting natural factors such as terrain, vegetation, climate, and hydrology for analysis. On the basis of evaluating the suitability of a single factor of human settlements, a Human Settlements Environment Index (HEI) is constructed to explore the natural suitability characteristics and spatial differences of human settlements in Hangzhou. The research results indicate that the natural suitability index of the human settlement environment in Hangzhou is between 0.06 and 0.93, with the overall pattern being the highest in the central region and gradually decreasing towards the northeast and southwest. The distribution area of more suitable areas is the widest, accounting for 26.55% of the province's area. The land area of highly suitable areas accounts for 22.69%, while the area of generally suitable areas accounts for 20.69%. The area of critical suitable areas and unsuitable areas is relatively low, accounting for 13.10% and 16.97%, respectively. Especially for the urban area of Hangzhou, low terrain undulation and flat terrain are its advantageous natural conditions, but its vegetation cover, climate, and hydrological conditions are inferior to other research areas except for the urban area. Therefore, based on the comprehensive analysis, its HEI is lower than the surrounding areas.*

***Keywords*— Geographic Information System (GIS), Hangzhou City, Human Settlements Environment Index (HEI), Relief Degree of Land Surface (RLDS), Natural Suitability.**

I. INTRODUCTION

Since the 20th century, productivity in various countries has developed rapidly, and some developed countries have entered the stage of modern urbanization. With reform and opening up, China has been in a state of rapid development, with rapid growth in Gross Domestic Product (GDP) and urban population. Currently, it is rapidly advancing with a posture of catching up with and surpassing the urbanization processes of developed countries in Europe and America. The advancement of urbanization has led to the rapid modernization of people's lives, gradually improving their living standards, and overall promoting an increase in people's survival and well-being. However, there are also many problems with its development process. Both developed and developing countries face similar challenges in the field of human settlements, such as land resources being encroached upon by extensive urban expansion, overcrowding in some cities, excessive consumption of natural resources, and continuous deterioration of the ecological environment. At the same time, with the improvement of living standards and the awakening of ecological awareness, the public's demand for a living environment is becoming increasingly high.

As early as the 1950s, based on the early architects and the post-World War II urban reconstruction planning work, the Greek scholar Doxiadis first proposed the concept of human settlement science, and the human settlement environment gradually became a hot research topic [1]. Academician Wu Liangyong in China introduced it and defined it as human settlement environment science [2]. In terms of definition, the living environment is first and foremost the place where humans live and reside, and it is the base on which humans rely for survival in nature. The core of the human settlement environment is "people", and the purpose of human settlement environment construction is to meet the needs of "human settlement".

The study area of this article, Hangzhou, has been known as the "paradise on earth" in China since ancient times, but as a new first-tier city with high urbanization, it inevitably faces some living problems. This study will analyze and evaluate the natural suitability of the human-settlements environment in Hangzhou in recent years based on GIS technology and provide scientific suggestions and data support for urban and rural pattern planning in order to improve its operational efficiency and people's happiness and health levels.

II. STYDY AREA

Hangzhou, also known as Lin'an, Qiantang, and Wulin for short, is located in the north of East China's Zhejiang Province, the southeast coast, the southern wing of the Yangtze Delta, the west end of Hangzhou Bay, the lower reaches of the Qiantang River, and the southern end of the Beijing-Hangzhou Grand Canal. It is an important central city in the Yangtze Delta and a transportation hub in southeast China, between 29° 11′~30° 33′ N and 118° 21′~120° 30′ E, covering an area of 16596 km2, accounting for 15.97% of the total area of the province (Figure 1). The research scope of this paper is the administrative region of Hangzhou City, which includes 10 districts, including Shangcheng District, Gongshu District, Xihu District, Binjiang District, Xiaoshan District, Yuhang District, Linping District, Qiantang District, Fuyang District, Lin'an District, Tonglu and Chun'an counties, one County-level city in charge of Jiande, Hangzhou Bay in the east, and land borders Anhui.

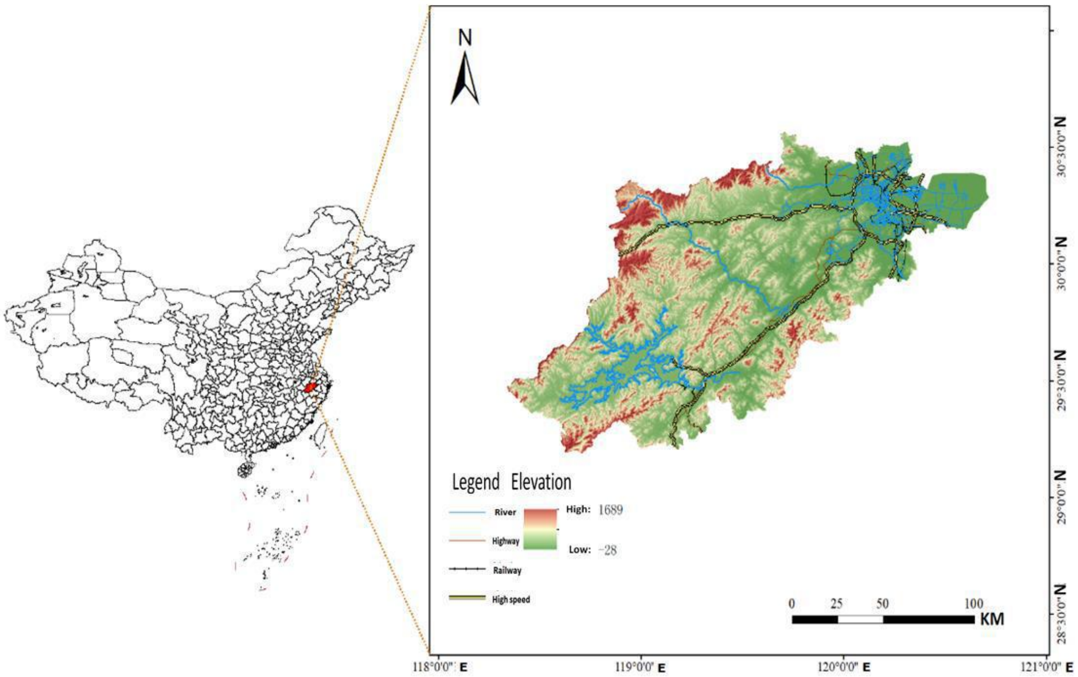

Fig.1: Geographical Location Map of Hangzhou City

2.1 Population Changes

As of 2022, the total number of permanent residents in Hangzhou has increased year by year, from 6.1605 million at the end of the 20th century to 12.376 million at the end of 2022. The urban population has increased from 2.1905 million in 1999 to 10.390 million in 2022, while the rural population has decreased from 3.970 million in 1998 to 1.986 million in 2022. The urban population has been increasing year by year, from the initial 35.60% to 83.96%, with an urbanization rate of 84.0% in the same year.

2.2 Topographic Conditions

Hangzhou is located in the south wing of the Yangtze Delta. According to its landform, it can be divided into coastal plain areas, hilly landforms, and piedmont valley areas [3]. Its topography is complex and diverse, and the terrain gradually decreases from west to east. It is influenced by the mountain and water systems and presents beautiful scenery like a Chinese water ink painting with mountains and rivers. The western part belongs to the middle and low hilly area of northwest Zhejiang, with low mountains and valleys arranged alternately and staggered with river basins, forming three landforms: Zhongshan deep valley, low mountain hill's wide valley, and river valley plain (Figure 2). The main mountain ranges include Tianmu Mountain, Baiji Mountain, and Longmen Mountain, with the highest peak being Qingliang Peak (1781 meters above sea level) of Baiji Mountain. The eastern part is the accumulation plain of northern Zhejiang, accounting for 34.4% of the total area of the city. The terrain is low and flat, with a dense network of rivers and lakes. Hangzhou has famous water bodies such as Qiandao Lake, Qiantang River, Dongtiaoxi River, and the Beijing Hangzhou Grand Canal, which are typical of "Jiangnan Water Town" [4].

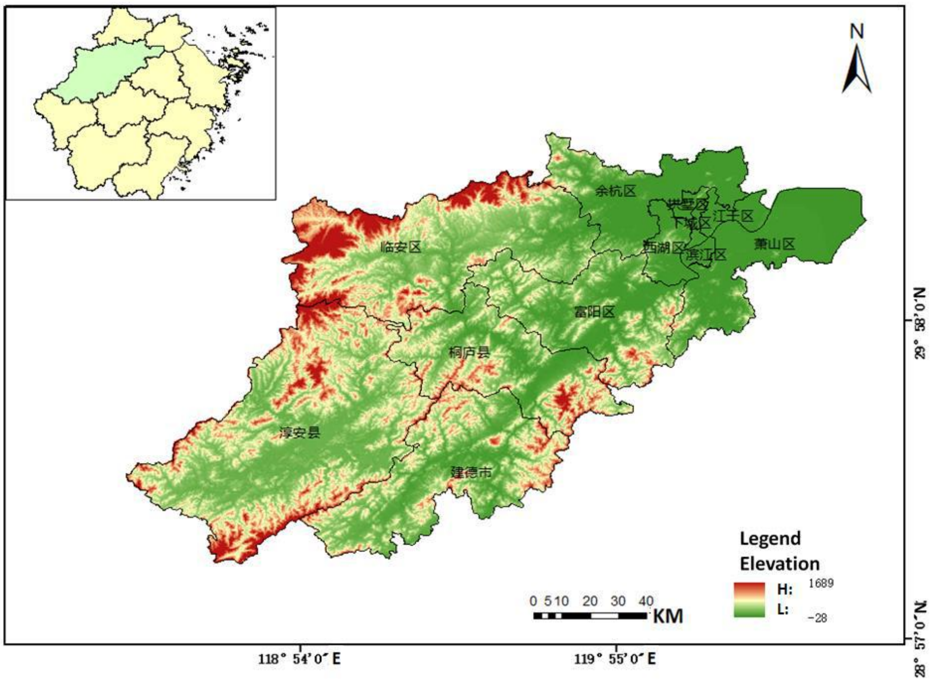

Fig.2: Topographic Overview of the Study Area

2.3 Climate Conditions

Hangzhou has a subtropical monsoon climate with four distinct seasons and abundant rainfall. The annual average temperature is 17.8 °C, the average relative humidity is 70.3%, the annual precipitation is 1454 mm, and the annual sunshine duration is 1765 hours. Nevertheless, the summer climate is hot and humid, making it one of the new four major furnaces. On the contrary, winter is cold and dry. The spring and autumn seasons have a pleasant climate and are the golden seasons for sightseeing and tourism.

2.4 Hydrologic regime

Hangzhou has a natural environment of rivers, lakes, and mountains. In addition, the urban reservoir accounts for 8% of the total area of the city. The surface river network in the region is densely distributed. The main rivers are the Qiantang River, East Caoxi, Beijing-Hangzhou Grand Canal, Hangzhou-Shanghai Line A, Hangzhou-Shanghai Line B, Xiao-Shao Canal, and Shangtang River. Among them, the Qiantang River is the largest water system, belonging to the tidal river. The lakes mainly include West Lake, Baima Lake, Xiang Lake, Xixi National Wetland Park, etc. [5].

III. METHODOLOGY

3.1 Data Sources

The data in this study mainly includes:

(1) DEM data with a spatial resolution of 30 m, sourced from Geospatial Data Clouds (GDC) (https://www.gscloud.cn/search);

(2) MODIS MOD13A3 NDVI data with a spatial resolution of 1KM from 2000 to 2022;

(3) Meteorological data, sourced from the National Meteorological Information Center-China Scientific Meteorological Data Network (http://data.cma.cn/), including the total monthly rainfall, average monthly temperature, relative humidity, etc. of 7 meteorological stations in the research area, with a period of 2019 to 2020;

(4) GlobeLand30 surface cover data, which divides land use types into 10 types: forest land, cultivated land, grassland, shrub land, wetland, water body, tundra, artificial surface, bare land, glacier, and permanent snow cover.

3.2 Methods

This article studies the natural suitability of human-settlements environment, mainly terrain conditions, climate conditions, hydrological conditions, and vegetation cover conditions. The operational steps and technical processes in the article are as follows (Figure 3): 1. Selecting four factors, it is namely terrain, land cover, climate, and hydrology, to construct an indicator system; 2. Using GIS technology, through vector data rasterizing, projection transformation, image clipping, and other processing, and resampling to a 250 m grid size for calculation; 3. On the basis of evaluating single factors such as terrain undulation, climate suitability, hydrological index, and vegetation status, a Hangzhou Human Settlements Environment Index (HEI) model based on GIS is constructed to quantitatively evaluate the suitability of human settlements.

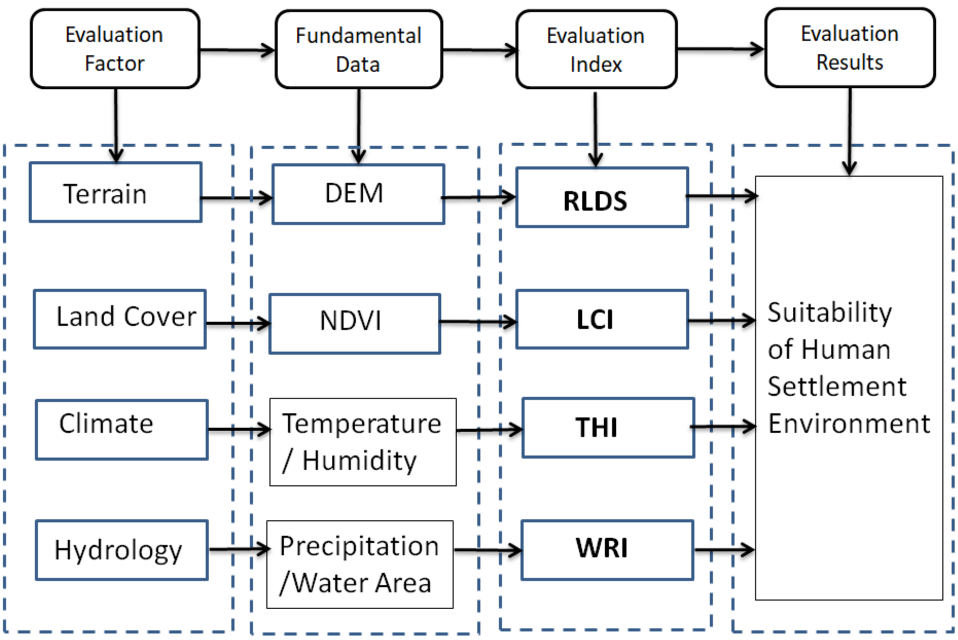

Fig.3：The Schema of the Study

3.3 Suitability Evaluation

The basic concept of suitability evaluation for human settlements is based on land suitability evaluation, which is usually used to evaluate the suitability of newly constructed land in the studied area. Its concept is generally defined as the suitability of land for a certain purpose under certain conditions and scope, that is, whether a certain land unit is to a large extent suitable for a certain utilization method. This concept extends to the suitability of human settlements and also means the suitability of environmental conditions for human settlements within the internal environment. In terms of evaluation methods, it is based on the spatial superposition of GIS, supplemented by the operational mode of spatial interaction.

There are many influencing factors that need to be considered when conducting analysis and evaluation, mainly the natural environment, economy, society, ecology, and various other environmental influencing factors. In general, suitability analysis considers ecological limiting factors, such as distance from water sources and ecologically sensitive areas, slope, elevation, etc. Thus, suitability evaluation in a narrow sense can be understood as ecological suitability evaluation. The main types of evaluations include farmland and crop suitability assessments, forest suitability assessments, grassland suitability assessments, urban construction land assessments, nature reserve assessments, as well as regional planning and environmental impact assessments. Among them, the most commonly used method is the suitability evaluation of urban construction land. This study uses the theoretical viewpoints and methods of suitability application as the basis for evaluation.

In addition, based on the convenience and limitations of obtaining research data, this study is based on the combination of water, soil, light, and heat conditions and selects four basic factors of terrain, land cover, climate, and hydrology as evaluation indicators, which are also the most basic indicators of environmental evaluation. The natural constituent factors of the living environment are the natural ecological environment foundation for local population development, economic and social development. Using the Human-Settlements Environment Index (HEI) model [6], quantitative research is conducted on the spatial regularity and natural suitability of human settlements through the evaluation and analysis of individual indicators of natural constituent elements and the spatial correlation of population density.

To develop a reasonable suitability evaluation, it is first necessary to establish a model, collect and organize various factors that affect the target, and calculate them with weights to obtain data and images within the evaluation range. Then, a hierarchical classification is carried out, dividing the research area into areas that are unsuitable, critical suitable, generally suitable, more suitable, highly suitable. Then, using data information such as the occupied area, location, and shape of these areas, the matching degree of the current construction land is analyzed, existing problems and solutions are analyzed, and scientific suggestions are finally proposed [7].

3.4 Data Processing and Evaluation

3.4.1 Suitability Evaluation of Topography (SET)

Terrain is an important component of the natural geographical environment and plays a fundamental role in the formation, development, and evolution of regional geographical environments. Relief Degree of Land Surface (RLDS) refers to the maximum elevation difference within a certain distance from the ground [8], which is essentially an extension of the concept of slope. The formula for calculating the terrain relief index is:

$$RLDS = ALT/1000 + \{[Max(H) - Min(H)] \cdot [1 - P(A)/A]\}/500 \quad (1)$$

In the formula, RLDS represents the terrain undulation index; ALT is the Height above mean sea level in a certain area (m); Max (H) and Min (H) are the highest and lowest elevations (m) within a certain area. All three parameters were calculated from DEM data using ArcMap neighborhood statistics, where A represents the total area of the region and P (A) is the flat area within the area.

3.4.2 Temperature-Humidity Index (THI)

Climate suitability is an important reference factor for people's survival and site selection. The quality of regional climate affects people's living experiences, and climate suitability evaluation has become an important component of human settlement environment evaluation. This article selects the temperature and humidity index as the indicator for evaluating the climate suitability of human settlements, and the formula is:

$$THI = 1.8t - 0.55(1 - f)(1.8t - 26) \quad (2)$$

In the formula, THI is the temperature and humidity index; T is the monthly average temperature (°C); F is the relative humidity (%), and this article uses the monthly average data of 7 meteorological stations in the study area for operation.

3.4.3 Hydrological Index (HI)

Hydrological conditions not only have an impact on terrain and topography but also have a significant impact on transportation, socio-economic development, and human habitation. Based on the scale of the study area and the availability of data acquisition, this article refers to the "hydrological index" (including precipitation and water area) proposed by relevant studies as the evaluation index [9-11]. The calculation formula for the hydrological index is:

$$WRI = \alpha P + \beta Wa \quad (3)$$

In the formula: WRI is the hydrological index; P and Wa are normalized annual precipitation and normalized water area, respectively; α and β are the weights of the ratio of annual precipitation to water area.

3.4.4 Vegetation Index (VI)

Plants are unique among the life materials that fix carbon, release oxygen, improve the environment, and form different seasonal landscapes. They are the lifeline of cities and the most important carriers for the sustainable development of human settlements. They are of great significance for improving the quality of human settlements. The formula is:

$$LCI = NDVI \times LTi \quad (4)$$

In the formula, LCI is the land cover index; NDVI is the Normalized Difference Vegetation Index; LTi is the weight of each land use in the study area; and i is the weight of each land use type. The weight values of each land use type are determined based on the vegetation cover index and the characteristics of the land use type in the study area.

3.4.5 Evaluating the Suitability of HEI

Based on the availability of the information in this article, the formula is:

$$HEI = \alpha \times NRDLS + \beta \times NLCI + \chi \times NTHI + \delta \times NWRI \quad (5)$$

In the formula, HEI represents the human-settlement environment index, ranging from 0 to 100, while NRDLS, NLCI, NTHI, and NWRI represent the standardized terrain relief, land cover index, temperature humidity index, and hydrological index, respectively. The weights corresponding to the four types of indices are determined as follows: α、β、χ、δ. Referring to the research results of Feng Zhiming [10] and others, the correlation coefficients between the natural single factor indices and population density are determined as follows: 0 305, 0.245, 0 295, and 0.155.

IV. ANALYSIS AND RESULTS

4.1 Terrain Conditions Impact on Human-Settlement Environment

There are various types of landforms in Hangzhou, with high terrain in the west and low terrain in the east. The western, central, and southern regions belong to the middle and low mountains and hills of western Zhejiang, while the northeastern region is the northern Zhejiang plain. The mountainous and hilly area of the city accounts for 65.6%, and the plain accounts for 26.4%. The topographic relief index increases from the northeast to the southwest on the whole. The area with the largest topographic relief is located in Lin'an District in the northwest, Chun'an and Tonglu County in the southeast. The highest altitude area in this area is more than 1000 meters, and the residential suitability is general. The area with the smallest terrain fluctuation is distributed in the northeast of Hangzhou City, mainly consisting of river network plains and coastal plains. The terrain is flat, with low elevation and high residential suitability (Figure 4).

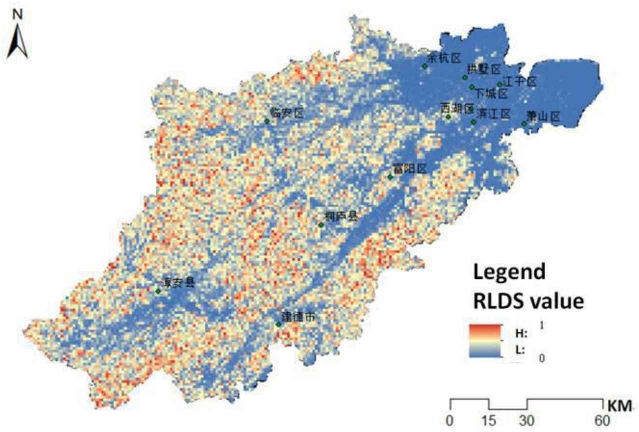

Fig.4: Spatial Pattern of RLDS in Hangzhou

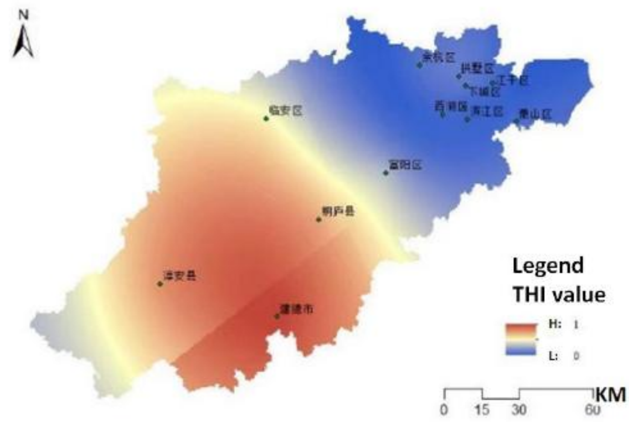

Fig.5: Spatial pattern of THI in Hangzhou

4.2 Climate Conditions Impact on Human-Settlement Environment

Hangzhou spans the southern and northern heat zones, and its climate characteristics have obvious regional characteristics. Influenced by the East Asian monsoon, mountains, and water bodies, it has formed a climate characterized by light, heat, and water in the same season and good coordination. The four seasons are distinct, with sufficient sunlight. The annual average temperature is 16.2 °C, the summer average temperature is 28.6 °C, the winter average temperature is 3.8 °C, the frost-free period is 230 to 260 days, and the average relative humidity is between 74% and 85%.

From the spatial distribution of the THI in Hangzhou, the overall trend shows an increasing trend from the northeast to the southwest (Figure 5). The areas with a lower THI are distributed in the central urban areas of Hangzhou, such as Yuhang, Binjiang, and Xiaoshan. Because the northeast is mostly plain, the terrain is flat, the terrain is open to the north, and the precipitation is relatively low. The thermal conditions are slightly worse than those in the lake area, and the suitability for living is relatively low. The higher areas are distributed in Chun'an County, Tonglu County, and Jiande. Because the Qiandao Lake District, Meicheng Liangjiang Plain, and Shouchang Basin in the southwest are surrounded by mountains on all sides, with water regulation in the middle, they are the areas with more precipitation, the best heat conditions, the longest frost-free period, and the best wintering conditions in Hangzhou, with higher residential suitability.

4.3 Hydrological Conditions Impact on Human-Settlement Environment

Hangzhou has a subtropical monsoon climate. In summer, it is often controlled by the Western Pacific Horse Latitudes. In winter, it is affected by the Siberian cold air mass. The climate is mild and humid, with an average annual rainfall of 1435 mm and abundant rainfall. The overall hydrologic index of Hangzhou is obviously higher in the southwest than in the northeast (Figure 6). The hydrologic index in the urban area of Hangzhou is the lowest, and the valley plain and basin in the middle are between the north and the south. The climate is suitable, and the precipitation is moderate. Chun'an County and Jiande in the southwest of the city, where Qiandao Lake District is located, have the highest index and high residential suitability.

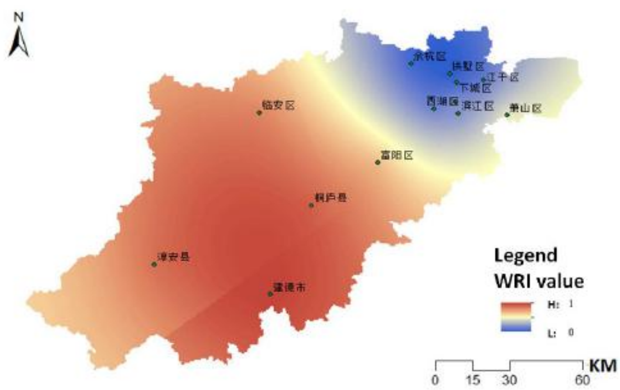

Fig.6: Spatial Pattern of Hydrological Index in Hangzhou

4.4 Vegetation Index Impact on Human-Settlement Environment

As a famous "forest city" in China, Hangzhou has a forest area of 16.89 million mu, a forest stock of 67.9 million cubic meters, and a forest cover of 66.85%. The vegetation index of the city shows a characteristic of being high in the southwest and low in the northeast, especially the lowest in the urban area (Figure 7). In fact, under the green development policy of the Hangzhou Municipal Government, the urban greening rate in the urban area is not low compared with other provincial capitals or economically developed cities, but compared with other regions in the study area, the urban area is highly developed and still expanding due to urbanization, has less vegetation coverage than other regions such as Lin'an District and Chun'an County, and the ecological environment is fragile.

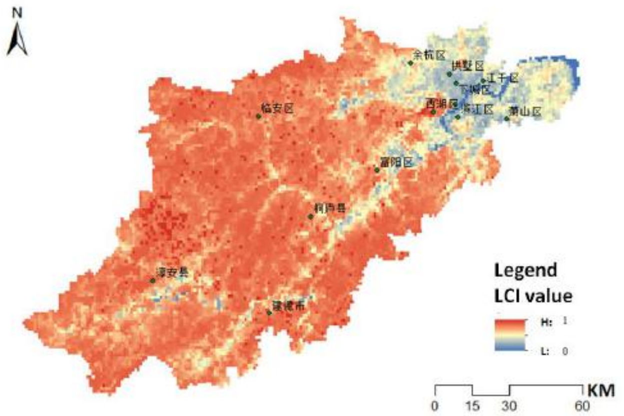

Fig.7: Spatial Pattern of Vegetation Index in Hangzhou

4.5 The Spatial Pattern of the Suitability of Human-Settlement Environment

The urban area of Hangzhou, which is located in the northeast of the study area, has advantages only in terms of topography, while areas such as Chun'an, Jiande, and Tonglu County, which are located in the southwest and middle of the study area, have better hydrothermal conditions and vegetation coverage than the urban area of Hangzhou, which does not coincide with the spatial distribution of population in Hangzhou.

The suitability analysis results of this study show that the human settlement suitability in Hangzhou is dominated by comparative more suitable and high suitable (Figure 8), which respectively account for 26.55% and 22.69% of the total area and are distributed in the northeast of Chun'an County, the southwest of Lin'an District, Jiande City, and the south of Tonglu County. Some of the landforms in these areas are low mountains, hills, river valleys, and basins. Although the topographic relief index is higher than that of the urban area of Hangzhou, the overall terrain does not constitute a limiting factor that destroys the livability of the area. And because the Qiandao Lake area, Meicheng Liangjiang Plain, and Shouchang Basin in the southwest are surrounded by mountains on four sides and there is water regulation in the middle, this area is an area with more precipitation, the best heat conditions, the longest frost-free period, and superior wintering conditions in Hangzhou, thereby having a higher suitability for living.

The generally suitable areas account for 20.69% of the total area and are mainly distributed in the central part of Hangzhou, namely the east of Lin'an District, the southwest of Chun'an County, and the south of Fuyang District. The valley plains and basins in the central part are between the north and the south. The climate is suitable, the precipitation is moderate, and the habitability is general. The proportion of critical suitable and unsuitable areas is relatively low, at 13.10% and 16.97%, respectively. The overall distribution of Hangzhou urban area is in these two areas, which is caused by the special geographical location and highly developed urbanization of Hangzhou urban area. It is worth noting that although the natural suitability of the human settlement environment in Hangzhou is inconsistent with the current population distribution, the overall human settlement suitability of the city cannot be ignored, which is the particularity of this study area.

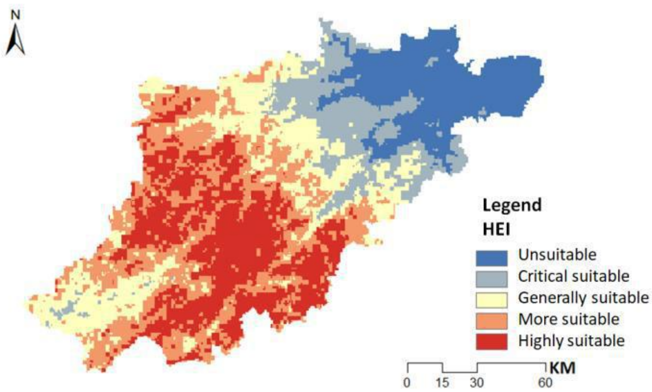

Fig.8: Spatial Pattern of Suitability Index

V. CONCLUSION

The human-settlement environment is the foundation of human survival and development; the surface space is closely related to human activities and is the base of human survival in nature; and it is the main place for humans to use and transform nature [12-13]. The evaluation of the natural suitability of human settlements is an important foundation and component of the functional zoning of population development in China at present. This paper constructs a comprehensive HEI model from four aspects of topography, climate, hydrology, and vegetation, analyzes the suitability of Hangzhou's human settlements environment with the help of the GIS Spatial analysis function, and provides the basis and support for the coordinated development and scientific planning of the human settlements environment construction in this area. The results of the analysis show that:

(1) The overall suitability of the living environment in Hangzhou is good, with low terrain undulation, good water and heat conditions, and high vegetation coverage. It is a famous forest city and a livable city.

(2) The current spatial pattern of population distribution in Hangzhou is inconsistent with the suitability of the living environment in the area because this study is based on natural factors. However, the geographical location and developed urbanization of the Hangzhou urban area make it inferior to other research areas in terms of water, heat, and vegetation, resulting in relatively unsuitable living conditions.

(3) Hangzhou has the widest distribution area of more suitable areas, accounting for 26.55% of the city's area, followed by highly suitable areas, accounting for 22.69% of the city's area, generally suitable areas, accounting for 20.69%, critical suitable areas, and unsuitable areas, accounting for 13.10% and 16.97%, respectively. The study results may due to the inaccuracy of DEM accuracy, the incompleteness of meteorological data, and the existence of personal equations, the subjectivity of evaluation method selection maybe affect the quality of research results. Next, data acquisition and processing methods should be further optimized to ensure scientific results.

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The Role of Communication Media in Increasing Skills and Value-Added Production of Beef Cattle Farming in Minahasa Regency

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Abstract— *This study aims to analyze the role of communication media, both conventional and digital media, in increasing the skills and productivity of cattle farmers in Minahasa District, Indonesia. The research was carried out using survey and sampling methods by purposive sampling with the main sample criteria, namely: having a computer or smartphone that uses it as a source of information and innovation in beef cattle farming science and technology. Research problem: conventional media is increasingly being replaced by digital media with computer/smartphone facilities, where cattle farmers obtain information on livestock science and technology at any time and anywhere with an internet communication network. What are the roles of communication media, both conventional media and digital media, in improving the skills and productivties of cattle farmers in Minahasa Regency. To answer the problem, analyzes of the relationship between independent variables were used, namely the role of print media (X_1), the role of classic electronic media (X_2), and the role of internet electronic media (X_3) with the dependent variable namely skills (Y_1) in raising beef cattle and value added (Y_2) to beef cattle production, and the effect of the cattle raising skill variable (Y_1) on the added value variable of cattle production (Y_2) using Pearson correlation analysis. The results of the analysis show that improving the skills of raising beef cattle in rural areas can be done by streamlining factors other than counseling/training in the field, also by utilizing digital communication media which are more populous. Beef cattle farming skills affect the added value of cattle farming, so that farmers' skills still need to be improved. The communication media factor, especially digital media, has become the dominant factor for improving cattle farming skills using digital electronic media (computers, tabs and smartphones). The technical skills of cattle farming due to digital communication media facilities affect the added value of both production and the economy of cattle farming, so that the skills of cattle farmers need to be improved through experience of science and technology content of cattle farming on digital communication media. Digital communication media that are often used by cattle farmers, such as social media YouTube, Facebook, blogs and others, which are increasingly being watched by cattle farmers.*

***Keywords*—Communication Media, YouTube, Facebook, Cattle Farming**

I. INTRODUCTION

Agricultural communication is a way of conveying understanding and knowledge of agricultural science and technology to the public, especially those working in the agricultural sector regarding information about science and technology in the agricultural sector including the sub-sectors of food crops, plantations, livestock, fisheries and forestry. Agricultural communication in its use for the field of extension is very important to support the absorption of information from extension workers, but what is happening now is that not all new technologies offered by extension agents are able to be absorbed and adopted by farmers (Anggriyani, 2015), so that farmers take advantage of alternative sources of information through communication media that can be done independently.

Increased knowledge, education, income and communication accessibility make it easier for farmers to find sources of information. The current phenomenon has been a change in the fulfillment of information needs and increasingly commercial farming behavior, which demands a change in the role, system and paradigm of agricultural extension (Puspadi, 2002 and Kissya, 2016). The internet is an alternative that can be used to bridge the information gap. Communication using internet media is technically and physically a new phenomenon in the process of human communication at the end of the 20th century and has become an integral part of society, education, industry and government (Effendi, 2010 and Oktavia, 2019).

Utilization of communication media is currently an important factor in channeling and conveying information and innovation to farmers both through print media, conventional electronic media and internet electronic media. The role of this communication media is expected to be able to add and increase the amount and quality of information relating to livestock farming in rural areas, thereby increasing the skills of farmers in running livestock farming. The role of the mass media, both print and electronic media, in providing information and increasing farmer knowledge, especially information related to technological innovation and livestock farming management.

Digitalization has enormous potential in Indonesia, including in the livestock sub-sector. Digitalization in the livestock sub-sector and the use of the latest technology such as the Internet of Things is believed to be able to significantly increase productivity in the livestock sub-sector from upstream to downstream (Ismail, 2019). The development of information and communication technology, such as computers and communication technology devices, can be used to bridge information and knowledge that is spread between those who master information and those who do not (Mulyandari et al., 2010, Nurmalina, 2012 and Listiana et al., 2019).

The internet telecommunications network and smartphone facilities that are already available support rural farmers to obtain information on livestock science and technology at anytime and anywhere as long as an internet communication network is available. Balitbangkominfo (2021) states that, in Minahasa Regency, the development of information and communication technology is very rapid so that it has affected the pattern of mobility and community development.

Beef cattle farm in Minahasa Regency is generally carried out in a traditional and small scale way, with a semi-commercial system, both breeding farms and feedlot farms. Sources of information on livestock science and technology come from government extension workers as well as conventional communication media and the increasingly popular digital media (computers/smartphones). The significantly factors effected farmers' income from cattle farming in Minahasa Regency were number of cattle, family labor, inseminator cost, cost of natural mating, value added of cattle and land size (Wantase and Paputungan, 2017). Regarding the process of the cattle marketing by cattle farmers in rural areas who want to sell their cattle, contact cattle traders to market their cattle in the cattle market, Kawangkoan, Minahasa Regency (Osak, et al. 2021).

The urgency of research, the role of communication media, both print media, classic electronic media (conventional) and internet electronic media (digital) in improving the farmer skills and value added in cattle production in Minahasa Regency. This study aims to analyze the role of communication media, from classical media (conventional) to current digital media, in improving the skills and the value added production of cattle farmers in Minahasa Regency.

II. RESEARCH METHODS

This research was carried out in Minahasa Regency, North Sulawesi Province, where 5 sub-districts with the largest population of cattle were selected according to BPS Minahasa (2021), namely Langowan Barat sub-district, Tompaso sub-district, Tompaso Barat sub-district, Kawangkoan sub-district and Kawangkoan Barat sub-district.

The data collection technique for this study used a survey method according to the instructions for collecting data (Sugiono, 2010). The primary data obtained follows from direct observation in the field, interviews and filling out of inquiry forms (questionnaires). The research was carried out using survey and sampling methods by purposive sampling with the main sample criteria, namely: having a computer or smartphone that uses it as a source of information and innovation in beef cattle farming science and technology. Variables and measurements:

(1) The role of print media communication media (X_1) in improving the skills of farmers, was measured using

a Likert rating scale through variable indicators in the questionnaire, namely Strongly disagree (score=1), Disagree (score=2), Undecided (score=3), Agree (score=4) and Strongly agree (score=5).

(2) The role of classical or conventional electronic media (X_2) in improving the skills of farmers, was measured using a Likert rating scale through the variable indicators in the questionnaire, namely Strongly disagree (score=1), Disagree (score=2), Undecided (score=3), Agree (score=4) and Strongly agree (score=5).

(3) The role of internet or digital electronic media (X_3) in improving the skills of farmers is measured using a Likert rating scale through variable indicators in the questionnaire, namely Strongly disagree (score=1), Disagree (score=2), Undecided (score=3), Agree (score=4) and Strongly agree (score=5).

(4) Cattle raising skills (Y_1), namely the skills of farmers to raise cattle after using communication media, be it print media, classic electronic media or internet electronic media, were measured using the Likert rating scale through variable indicators in the questionnaire, namely very low (score=1), Low (score=2), Same (score=3), High (score=4) and Very High (score=5).

(5) The added value of cattle production (Y_2), namely the additional production value after the use of communication media, be it print media, classic electronic media or internet electronic media, was measured using the Likert rating scale through the variable indicators in the questionnaire, namely very little (score=1), Slightly (score=2), Equal (score=3), Large (score=4) and Very Large (score=5).

The analysis will be used to measure the relationship between the independent variables of the role of the communication media, be it print media (X_1), the role of classical electronic media (X_2), and the role of internet electronic media (X_3) with the dependent variable Value added cattle production (Y_1), and the effect of the cattle raising skill variable (Y_1) on the added value variable of cattle production (Y_2) using Pearson correlation analysis according to the formula (Riduwan, 2003), as follows:

$$r = \frac{N.\ \sum XY - (\sum X).(\sum Y)}{\sqrt{\{N.\sum X^2 - (\sum X)^2\}.\{N.\sum Y^2 - (\sum Y)^2\}}}$$

The level or category of the closeness of the relationship between variables can be seen in Table 1. To test the significance of Pearson correlation (r), the t-test is used with the formula:

$$t = \frac{r\sqrt{N-1}}{\sqrt{1-r^2}}$$

For this research:

r = correlation coefficient between X_i and Y_j variables

t = significance coefficient value

N = number of observations

X_i = the role of communication media networks, both print media (X_1), the role of classical electronic media (X_2), and the role of internet electronic media (X_3)

Y_1 = farmer skills in cattle production

Y_2 = added value of cattle production

Table 1. Interpretation of the Correlation Coefficient

Coefficient Intervals	Relationship Level
0.800 – 1.000	Hight
0.600 – 0.800	Strong
0.400 – 0.600	Enough
0.200 – 0.400	Low
0.000 – 0.100	Very low

Source: Riduwan, 2003

III. RESULTS AND DISCUSSION

Minahasa Regency has superior livestock, namely beef cattle, most of which are spread over several sub-districts, namely Langowan Barat, Tompaso, Tompaso Barat, Kawangkoan and Kawangkoan Barat sub-districts. The development of the cattle business in the five sub-districts above is very fluctuating, due to the existence of the blantic cattle market in Kawangkoan, where the five sub-districts above are located or relatively close to the cattle market. In the cattle market there are quite a lot of intermediary traders (blantic), where the intermediary determines the price of cattle according to body weight which the cattle farmer does not know (Elly, 2010), and barter, non-barter and trade-in transactions of cattle occur (Kimbal, 2012). The blantic cattle market can have a positive impact on economic development, the cattle business can increase farmer households' income, provide animal food, provide raw materials for various industries and create jobs for the community, especially in Minahasa Regency and generally in North Sulawesi Province. Minahasa Regency is one of the areas that has the largest number of cattle population in North Sulawesi.

Characteristics of Respondents

The results showed that the characteristics of respondents based on gender as a whole were male as many as 36 farmers with a percentage of 90% and interestingly there were women as many as 4 farmer or 10% as cattle farmers either helping their husbands or assisted by sons. This shows that even though the cattle farming requires more manpower and generally the men are stronger at work, there are women as cattle farmers. This is in line with research from Ervina, et al (2019) that the majority of livestock farming actors are male because this work requires more physical strength, but does not rule out the possibility that this work is carried out by women.

Characteristics of respondents based on age showed that most of the age of the farmers, namely at the age of 46-60 years, amounted to 22 farmers with a percentage of 55%, while the smallest age range was at the age of 15-30 years, amounting to 3 farmers or 7.50%. Putri, et al (2019) stated that livestock farming actors aged 15-60 years are called working age or productive age, ages 0-14 are called young or not productive age, and those over 60 years are called old age.

The results showed that the characteristics of respondents based on the level of education of cattle farmers were high school graduates or the equivalent of 22 people or 55% of the total sample, while the least at the education level of elementary and tertiary education were 3 people each with a percentage of 7.50%. There are 12 cow farmers who have junior high school education with a percentage of 30%. The level of education is an important factor that influences the mindset and performance of farmers in conducting cattle farming. This is in line with Waris, et al (2019) stating that the education level of cattle farmers, both formal and non-formal, will affect the way of thinking and performance in the farming being carried out.

Livestock farming experience is an important capital in the success of cattle farming, because the level of work experience will affect the mindset in implementing innovation. In general, all respondents had good experience in raising cattle, where most of them had experience of 21-30 years (22.50%) and 31-40 years (52.50%). Otoluwa, et al (2016) that the longer farmers cultivate beef cattle, it allows them to learn more from their experience, so that they can easily accept technological innovations related to the farming being carried out.

Analysis of the role of communication media in improving livestock farmers' skills and value added production of cattle farmers

Agricultural communication in the field of extension is very important to support the absorption of information from extension workers to farmers, so that messages conveyed by agricultural extension workers can be received and implemented properly and correctly. However, what happened was that not all of the new technologies offered by extension workers were able to be absorbed or adopted by farmers (Anggriyani, 2015). For the effectiveness of the communication process for the absorption of information from extension agents to farmers, a delivery medium called communication media is needed. Communication media has an important role in the extension communication process. Extension communication media as a set of tools used by extension agents in communicating with target breeders. The tools used are known as media, while communication is a way of delivery. The role of communication media, both print media (such as newspapers, magazines, leaflets/brochures and so on), conventional/classical electronic media (radio and television) and internet electronic media (computers and smartphones) is so important in improving the skills of livestock farmers and added value production of cattle farms.

Statistical analysis used Pearson correlation analysis to measure the role of independent variables (influence), namely print media (X_1), classic electronic media (X_2), and digital electronic media (X_3) on the dependent variable, namely skills (Y_1) and added value (Y_2) of cattle farming, also the effect of skills (Y_1) on the added value (Y_2) of cattle farming.

Table 2 Results of Pearson Correlation Analysis

Correlations

		X_1	X_2	X_3	Y_1	Y_2
X_1	Pearson Correlation	1	.107	-.207	-.241	-.293
	Sig. (2-tailed)		.511	.201	.134	.067
	N	40	40	40	40	40
X_2	Pearson Correlation	.107	1	-.346*	-.571**	-.667**
	Sig. (2-tailed)	.511		.029	.000	.000
	N	40	40	40	40	40
X_3	Pearson Correlation	-.207	-.346*	1	.775**	.828**
	Sig. (2-tailed)	.201	.029		.000	.000
	N	40	40	40	40	40
Y_1	Pearson Correlation	-.241	-.571**	.775**	1	.903**

	Sig. (2-tailed)	.134	.000	.000		.000
	N	40	40	40	40	40
Y_2	Pearson Correlation	-.293	-.667**	.828**	.903**	1
	Sig. (2-tailed)	.067	.000	.000	.000	
	N	40	40	40	40	40

*. Correlation is significant at the 0.05 level.

**. Correlation is significant at the 0.01 level.

The results of the analysis can be seen in Table 2 showing the results of the correlation analysis or variable relationship. It can be seen that the correlation value of the variable role of print media (X_1) with the cattle farming skill variable (Y_1) is -0.241, negatively correlated means it can reduce skills even though it is classified as a low correlation with a significance level of 0.134 (p>0.05), which means that the role of print media no longer plays a role in increasing the skills of cattle farmers.

Likewise, the correlation of the role of print media (X_1) on the added value of cattle production (Y_2) of -0.293 is low and negative, even with a significance level of 0.067 (p <0.05) indicating that there is a significant effect on the added value of cattle production.. This can be due to print media such as newspapers, magazines, leaflets being read over and over again to try to increase the economic value of cattle, for example in terms of cattle marketing. Ruyadi et al (2017) reported that the highest frequency of the use of communication media by agricultural extension officers in the form of brochures and leaflets by agricultural extension officers was not too high, where brochures and leaflets served as supporting media for agricultural extension activities. The reason for using brochures and leaflets is because the information contained in brochures and leaflets is in accordance with the needs in supporting agricultural extension activities, with the aim of increasing knowledge in supporting agricultural extension activities.

The results of the correlation analysis or relationship between the role variable of classical electronic media (X_2) and the variable cattle farming skills (Y_1) are -0.571 with a negative correlation, but it has a significance level of 0.000 (p<0.01), which means that the role of classical electronic media can reduce the increase in cattle farming skills. Likewise, the correlation of the role of the print media (X_1) on the added value of cattle production (Y_2) is -0.667 with a negative correlation, with a significance level of 0.000 (p<0.01) indicating a strong effect on reducing the increase in the added value of cattle farming. This could be due to the fact that classic electronic media such as television and radio are being watched less by farmers for agricultural science and technology broadcast programs.

The results of the correlation analysis of the relationship between the variable role of digital electronic media (X_3) and the cattle raising skill variable (Y_1) of 0.775 are classified as very strong correlation and have a very real significance level of 0.000 (p<0.01), which means the role of digital internet electronic media plays an important role in improving the skills of raising cattle farming. Likewise, the correlation of the role of digital internet electronic media (X_1) on the added value of cattle production (Y_2) of 0.828 is classified as very strong or high, with a very significance level of 0.000 (p<0.01) indicating that there is a very significant influence. This is because internet electronic media such as YouTube, Facebook, Instagram, blogs and others are increasingly being watched by the public and farmer, which can be watched directly or the recordings can be watched online at any time. In addition, those social media have posted various appropriate and practical sciences and technologies that can improve the skills of farmers both technically and economically which lead to increased productivity, especially the added value of cattle production.

The results of the correlation analysis of the relationship between the variable cattle farming skills (Y_1) and the variable added value of cattle production (Y_2) of 0.903 are classified as high or very strong correlations and have a very real significance level of 0.000 (p<0.01), which means the role of cattle raising skills variable plays a very important role in increasing the added value of cattle production. These results indicated that increasing the skills of cattle farmers, will further increase the economic added value of cattle farming.

The strategy that can be implemented is to develop agricultural production practices using appropriate techniques and non-agricultural businesses that are environmentally friendly and in accordance with the principles of sustainable development (Sondakh, et al., 2016). The production of cattle farming is mainly to increase the added value of cattle farming economically in increasing the household income of livestock farmers. The results of the analysis have shown that the working skills of cattle farmers affect the added value of cattle farming, so that the skills of cattle farmers need to be improved. To improve the skills of farmers, like it or not, it has to be done by making the dominant factors more effective according to the latest developments in digital communication media.

IV. CONCLUSION

The communication media factor, especially digital media, has become the dominant factor for improving cattle farming skills using digital electronic media (computers, tabs and smartphones). The technical skills of cattle farming due to digital communication media facilities affect the added value of both production and the economy of cattle farming, so that the skills of cattle farmers need to be improved through experience of science and technology content of cattle farming on digital communication media. Digital communication media that are often used by cattle farmers, such as social media YouTube, Facebook, blogs and others, which are increasingly being watched by cattle farmers.

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Impact of Maize Seed Moisture Content Reduction on Germination Parameters as Influenced by Sun Drying

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Abstract**—** *When growing seedlings for commercial purposes, excellent seed quality is crucial. Seed quality influences germination rate because seeds that sprout slower typically produce lower-quality seedlings. In numerous plants, seed moisture content has a significant impact on seed germinating speed. This study investigates the impact of various moisture content (MC) reductions on maize germination parameters and determines the moisture content level essential for maize germination. A comprehensive laboratory experiment was laid out in a completely randomized design (CRD) consisting of five treatments and three replicates. The treatment levels were maize seeds not sun-dried after collection (control), maize seed sun-dried for 3 days, maize seed sun-dried for 6 days, maize seed sun-dried for 9 days, and maize seed sun-dried for 12 days. Data were obtained on shoot length, root length, seedling length, germination percentage (GP), germination energy (GE), mean germination time (MGT), and seedling vigour index (SVI). All germination parameters were taken and calculated and the experiment was terminated two weeks after planting (WAP). Results indicated that the control significantly (p<0.05) performed better than other treatments for all the germination parameters. It was determined that maize with moisture content of 9.4% and below had low germination ability. This study concludes that the impacts of reduced moisture content on maize's physical properties (quality, texture, shape), chemical composition (fat and starch content), and biological characteristics (seed viability) resulted in the low germination ability of maize seeds.*

Keywords**— *Germination parameters, maize seed, moisture content reduction, sun drying.***

I. INTRODUCTION

Maize, commonly referred to as corn is widely grown around the world (Awopegba *et al.*, 2017; Suleiman *et al.*, 2013). Maize is a member of the grass family (family: Poaceae, previously Gramineae) (Badu-Apraku and Fakorede, 2017). Globally, maize grain is an important source of food, feed, and raw materials for industrial processes. Starch, protein, oil, and fiber, which make up around 95% of the biomass of harvested grains, are the main nutritious components (Bheemanahalli *et al.*, 2022; Venkatesh *et al*, 2016). Maize is a staple grain crop grown in temperate and tropical locations across the globe in a variety of soil types and climates (Khaeim *et al.*, 2022).

For operations including the production, selling, and processing of maize (*Zea mays* L.), as well as serving as the basis for research, grain moisture content (GMC) measurement precision is crucial (Gao *et al.*, 2021). A key element in maintaining resistant seeds quality is moisture content. The odd association of subcellular water with macromolecular surfaces in seeds ensures membrane and macromolecule preservation (Patil and Krishna, 2016). The loss of water during the drying process results in several metabolic changes that affect the control of growth regulators, the quantity and type of proteins and carbohydrates, the presence of free radicals, and the physical water status, among other things, and causes the deterioration process to begin. When the germination percentage was significantly reduced, this moisture was called critical moisture content. When there was no germination, it was called fatal moisture content (Patil and Krishna, 2016).

Maize deformation results from high moisture content in storage. Maize is dried for planting in a variety of traditional ways, including sun, hot air, and other methods. In addition, maize seeds are damaged when dried at high temperatures (Nair *et al.*, 2011). Drying seeds artificially requires removing extra moisture. Seed drying lowers respiration while also preventing seed quality from deteriorating in storage due to microbial development and insect and mite activity (El-Abady, 2014). Maize seeds lose moisture during drying, causing physical changes. Changes in mass, volume, density, colour, and porosity are typically used to characterize physical changes in cereal grains during growth or a decrease in moisture content (Cârlescu *et al*., 2023). However, moisture-rich maize should not be stored.

Germination is the process through which a seed or spore grows into a plant following a period of inactivity (Wade *et al.*, 2016). Seed germination is a protrusion of the radicle from the tissue(s) enclosing it (Soltani *et al.*, 2015). A seedling grows and develops during germination, a physiological process that sets off a chain reaction of biological and biochemical events (Khaeim *et al.*, 2022; Poudel *et al.*, 2019). Rapid water absorption by seeds during the imbibition phase of germination causes the seed coat to stretch and soften at the right temperature (Fu *et al.*, 2021). The seed's internal physiological processes are then triggered, and respiration begins (Itroutwar *et al.*, 2020; Koornneef *et al.*, 2002). Last but not least, the cracked seed coatings enable the development of radicles and plumules. This means that, as a result, it begins with the dry, dormant seed absorbing water and ends with the radicle emerging as a result of the lengthening of the embryo axis (Fu *et al.*, 2021). Several coordinated physiological and morphogenetic processes, such as seed energy transfer, endospermic nutrition absorption, and physiological and metabolic changes are all involved in this process (Nciizah *et al.*, 2020).

Germination impacts maize yield and quality (Xue *et al.*, 2021). Plants develop fundamentally from a single seed into a plant (Lara-Núñez *et al.*, 2021). The interaction of environmental variables and seed physiological conditions regulates germination (McCormick *et al.*, 2016). Germination is influenced by temperature, light, and water availability (McCormick *et al.*, 2016). Seed germination reflects population size, distribution, and abundance (Khaeim *et al.*, 2022). Seed physiological response to overlapping extrinsic and abiotic stimuli impacts propagation success (Norgrove, 2021).

Maize is traditionally dried outside in the sun. To dry maize, lay the grains out on a mat and expose them to the sun (Ntwali *et al.*, 2021). Sun drying is an alternative and affordable method for smallholder farmers of reducing maize moisture content (Kaminski and Christiaensen, 2014). Uneven moisture removal, exposure to insects, rodents, birds, and dust, and failure to obtain an acceptable moisture level due to a significant dependence on weather conditions are the method's drawbacks for sun-drying (Fudholi *et al.*, 2010). However, this study investigates the impact of various moisture content (MC) reductions on maize germination parameters and determines the level of moisture content essential for maize germination.

II. MATERIALS AND METHODS

Experimental Site

A comprehensive laboratory experiment was conducted in the Agricultural Technology Department of Ekiti State Polytechnic, Isan Ekiti. It is located in the rainforest agroecological zone in southwest Nigeria. The laboratory has a constant 22^0C temperature. The experiment was carried out between January 12th and February 7th, 2023.

Source of Material

Improved maize variety **(**Mastrop 143) was collected from Sunbeth Global Concepts, Ondo State, Nigeria.

Experimental Design

This study consists of five (5) treatments. Ten (10) seeds were planted per replicate which makes it thirty (30) seeds per treatment as each treatment was replicated three times. In this study, the experimental design was completely randomized (CRD). The treatment levels were:

T_1 = Maize seed not sun-dried after collection (Control)

T_2 = Maize seed sun-dried for 3 days

T_3 = Maize seed sun-dried for 6 days

T_4 = Maize seed sun-dried for 9 days

T_5 = Maize seed sun-dried for 12 days

For all the sun-dried maize, it was sun-dried for 7 hours between 9:00 am and 4:00 pm daily.

Planting and Cultural Practices

Desiccators were used to store maize seeds not to absorb moisture after sun drying. Maize seed was uniformly planted at 3 cm depth. Maize seeds were planted directly in moisture containers containing sterilized loam soil and arranged on the slab in the Agricultural Technology Laboratory. A maize seed was planted inside each moisture container and water was applied every day. All germination parameters were taken and calculated and the experiment was terminated two weeks after planting (WAP).

Data Collections

Immediately after the collection of maize seeds, the moisture content was determined with a moisture meter before planting. The moisture content at every stage of planting was also determined with a moisture meter. Germination parameters were taken every 24 hours up to two weeks after planting. Data were obtained on plant shoot length (plumule), plant root length (radicle), seedling length, germination percentage (GP), germination energy (GE), mean germination time (MGT), and seedling vigour index (SVI).

- Plant shoot length was determined using measuring tape in centimetres. Plant root length was determined with a measuring tape after uprooting the plant. The seedling length was obtained by combining plant shoot length and plant root length.

- $GP = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds planted}} \times 100$ (Anupama *et al.*, 2014) (1)
- $GE = \frac{\text{Number of seeds germinated at 144 hours}}{\text{Total number of seeds planted}} \times 100$ (2)
- $MGT = \frac{\Sigma (n \times d)}{N}$ (Kulkarni *et al.*, 2007) (3)

where n = Number of seeds germinated on each day, d = Number of days from the beginning of the test, and N = Total number of seeds germinated at the termination of the experiment.

- SVI = Seedling Length × Germination Percentage (Anupama *et al.*, 2014) (4)

Data Analysis

The data obtained on the germination parameters were analyzed statistically using Analysis of Variance. Data were examined with SPSS version 21 and Duncan's Multiple Range Test (DMRT) was used to compare treatment means.

III. RESULTS AND DISCUSSION

Table 1 shows the moisture content of maize seeds influenced by sun drying. The moisture content of maize sun-dried for 3 days (T_2), maize sun-dried for 6 days (T_3), maize sun-dried for 9 days (T_4), and maize sun-dried for 12 days (T_5) were 12.0%, 9.4%, 6.9%, and 5.2% respectively while the moisture content of the control was 14.6%. Patil and Krishna (2016) discovered that a reduction in the moisture content of seeds occurs during drying under shade and that the longer the time of drying the more the reduction of moisture content. In other words, the longer the sun-drying duration, the lower the moisture content of maize seeds.

Table 1: Moisture Content of Maize Influenced by Sun Drying

Treatments	**Moisture Content (%)**
T_1= Control (Maize not sun-dried after collection)	14.6
T_2= Maize sun-dried for 3 days	12.0
T_3= Maize sun-dried for 6 days	9.4
T_4= Maize sun-dried for 9 days	6.9
T_5= Maize sun-dried for 12 days	5.2

Table 2 shows the impact of moisture content reduction on maize shoot and seedling length as influenced by sun drying. There were significant differences among the treatments in root length. T_1 had the longest root length while T_5 had the least. Significant differences in shoot and seedling length occurred among the treatments. T_1 had the longest shoot and seedling length and the shortest was T_5.

Table 2: Impact of Moisture Content Reduction on Maize Shoot and Seedling Length as Influenced by Sun Drying

Treatments	Root length (cm)	Shoot length (cm)	Seedling length (cm)
T_1	8.28^{a}	7.22^{a}	15.50^{a}
T_2	7.70^{b}	6.70^{b}	14.40^{b}
T_3	7.25^{c}	6.16^{c}	13.41^{c}
T_4	7.00^{cd}	5.50^{d}	12.50^{d}
T_5	6.00^{e}	4.45^{e}	10.45^{e}

* Means followed by the same letter in the same column are not significantly (p> 0.05) different as indicated by Duncan Multiple Range Test.

Table 3 shows the impact of moisture content reduction on germination parameters as influenced by sun drying. Germination parameters under consideration were germination percentage, germination energy, and seedling vigour index. Significantly, higher seed germination (93.33 percent) was observed in seeds planted immediately after collection (T_1). In addition, the maize seeds sun-dried for 3 days (T_2) performed relatively well compared with the control in terms of germination percentage. The lowest seed germination (13.33 percent) was observed in seeds sun-dried for 12 days (T_5). In general, seeds' moisture content dropped as drying time increased, inhibiting seed germination. Broschat and Donselman's (1986) findings in the tropical species corroborated this study. As for the germination energy, the data were taken 6 days after planting. There were significant differences among the treatments**.** Significantly, T_1 germinated faster than every other treatment while the least was recorded for T_5. The highest seedling vigour was observed for T_1, while it declined as maize moisture content reduced across other treatments.

Table 3: Impact of Moisture Content Reduction on Germination Parameters as Influenced by ***Sun Drying***

Treatments	GP (%)	GE (%)	SVI
T_1	93.33^{a}	90.00^{a}	1446.62^{a}
T_2	83.33^{ab}	53.33^{b}	1199.95^{b}
T_3	46.67^{c}	40.00^{c}	625.84^{c}
T_4	26.67^{d}	23.33^{d}	333.38^{d}
T_5	13.33^{e}	6.6^{e}	139.30^{e}

*****Means followed by the same letter in the same column are not significantly ($p > 0.05$) different as indicated by Duncan Multiple Range Test.

Figure 1 shows the mean germination time influenced by sun-drying maize seeds. Reduction in maize seeds' moisture content caused an increase in germination time. There was an increase in the mean germination time as the moisture content decreased. T_1 with the highest moisture content has the lowest mean germination time compared to other treatments, which makes it better than the rest of the treatments. The fastest germination has the lowest mean germination time. Fetouh and Hassan (2014) established that faster germination leads to lower values of the speed index known as mean germination time (MGT). Reduction in moisture content seriously affected T_4 and T_5.

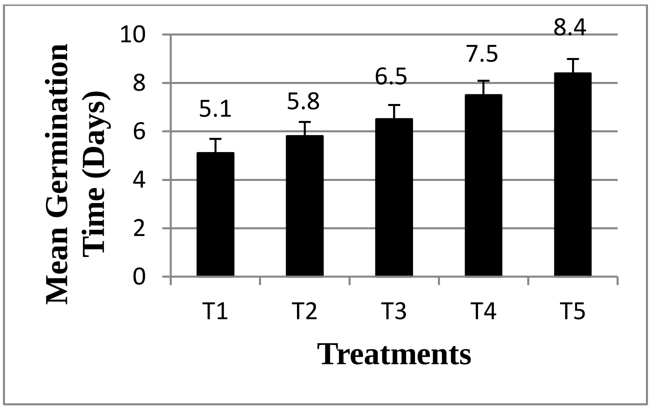

Fig. 1: Mean Germination Time Influenced by Sun Drying Maize Seeds

IV. CONCLUSION

This study demonstrated that reducing maize moisture content below 12% affects germination of maize. Germination percentage varied between 93.33% and 83.33% when the moisture content was 14.6% and 12%. Below that, 46.67% was obtained as a germination percentage for maize at 9.4% moisture content. Other germination parameters such; as germination energy, seedling vigour index, and mean germination time were also considered. It was determined that maize with 9.4% moisture content had low germination ability. This study concludes that the impacts of reduced moisture content on maize's physical properties (quality, texture, shape), chemical composition (fat and starch content), and biological characteristics (seed viability) resulted in maize seeds' low germination ability.

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Spatial-Temporal Evolution Characteristics of Vegetation Coverage and Urbanization Expansion in Dongguan Based on Remote Sensing

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***Abstract*— *The purpose of this study is to use the Landsat satellite image of Dongguan from 2005 to 2021, combining the dimidiate pixel model and stochastic matrix method, to calculate the vegetation coverage grade and land use type area, express the urbanization process with construction land, and analyze the relationship between the temporal and spatial evolution characteristics of vegetation coverage and urbanization expansion. The results indicate that: (1) The overall distribution of vegetation coverage is consistent, showing a spatial distribution characteristic of "high in the east, low in the west, and lowest in the north". (2) During this period, the overall coverage area of medium low, medium, and medium high vegetation decreased, while both low and high vegetation coverage areas increased. (3) The area of construction land has increased significantly, with the increased built-up area coming from bare land, followed by vegetation and water bodies. (4) The spatio-temporal evolution characteristics of vegetation coverage are closely related to urbanization expansion. This study can provide reasonable scientific data support and an effective decision-making basis for evaluating the regional ecological environment, construction, and urban development of Dongguan City.*

Keywords*— Dimidiate Pixel Model (DPM); Support Vector Machine (SVM); Land Use Type; Urbanization; Stochastic Matrix; Remote Sensing

I. INTRODUCTION

With the continuous expansion of China's urbanization, many problems have arisen. The process has negative and positive externalities for vegetation coverage. Many regions are occupying a large amount of ecological land during the rapid urbanization process, with some of it being transformed into impermeable surfaces to support human habitation, roads, and other infrastructure. Meanwhile, during the process of urbanization, a large amount of rural labor is transferred to secondary and tertiary industries, resulting in idle rural land and the restoration of forests.

In addition, with economic growth and residents' awareness of environmental protection rising, cities can increase and restore vegetation resources through institutional and policy reform measures, making urbanization and vegetation coverage develop in harmony. Although urbanization brings burdens, it will also bring positive externality to vegetation coverage [1]

In this context, this paper takes Dongguan City, Guangdong Province, as a confirmatory research area, and uses the Landsat data from 2005 to 2021 to carry out research on the estimation of vegetation coverage in the city, to quantitatively analyze its spatial and temporal distribution and change characteristics, and then to explore the correlation between the change trend of vegetation coverage and the level of urbanization. So as to clarify the spatial and temporal change law of vegetation and the pattern of urbanization expansion, which is the regional ecological environment construction and urban development of Dongguan City, provide reasonable and scientific data support and an effective basis for decision-making.

II. STUDY AREA AND DATA SOURCES

2.1 Study Area

The total area of Dongguan City is about 2542.67 km^2, between 113° 31′ -114° 15′ E and 22° 39′ -23° 09′ N. Located in the south-central part of Guangdong Province, on the east bank of the Pearl River Estuary and the Pearl River Delta at the lower reaches of the Dongjiang River, it borders Huizhou City in the east, Zengcheng District of Guangzhou City in the north, Panyu District of Guangzhou City across the sea in the west, and Bao'an District of Shenzhen City in the south. It is an important waterway between Guangzhou and Hong Kong. It currently governs 32 townships (4 streets, 28 towns), 546 village committees, and 132 neighborhood committees..

Its climate conditions are a subtropical monsoon climate with a long summer without winter, an annual average temperature of 23.3 °C, abundant rainfall, and an annual precipitation of 2042.6 mm. Topographic conditions are mainly hilly tableland and Alluvial plains. The mountains in the southeast are large and concentrated, with an altitude of 200–600 meters, a gradient of about 30°, and large fluctuations. The central and southern regions are mainly composed of low mountains and hills. The northeast is dominated by Alluvial plains with an altitude of 30–80 meters. The slope is relatively small, and the terrain undulates gently (Figure 1). The Forest cover of the city reached 37.4%, and the greening coverage of the central urban area reached 47.51%.

Throughout the history of Dongguan's urban development, in the past 40 years, it has developed from an agricultural county with a gross regional product of only 600 million yuan to a global manufacturing base for multinational companies with a total economic volume of more than 700 billion yuan. It is the first of the "Four Tigers of Guangdong", known as the "World Factory", and an important transportation hub and foreign trade port in Guangdong. This process has made the process of urbanization and change dramatic. By the end of 2022, Dongguan will have a permanent resident population of 10.437 million, including 9.6281 million urban residents, with an urbanization rate of 92.25%. The constructed area will expand from less than 5 square kilometers to more than 900 square kilometers today, surpassing many provincial capitals and ranking on the new front line.

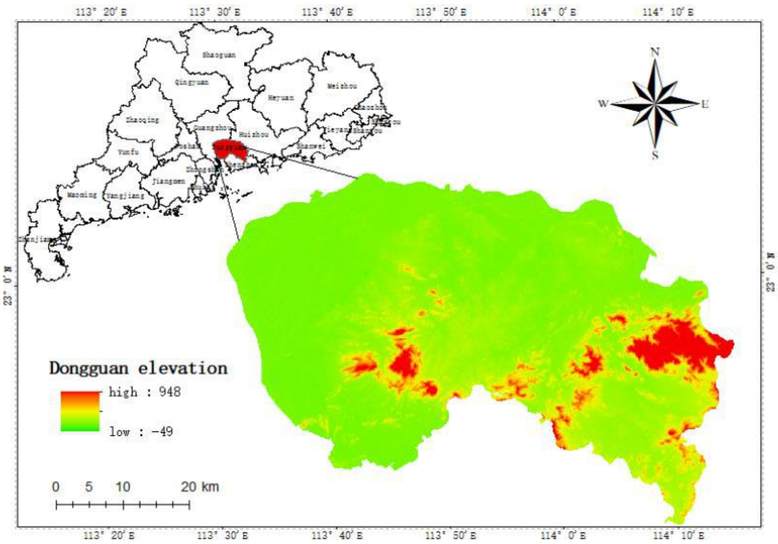

Fig.1 Location Map of Dongguan City

2.2 Data Sources

In this study, remote sensing images, including Landsat 5 TM remote sensing imagery from 2005 and 2009 and Landsat 8 OLI from 2015 and 2021, with a spatial resolution of 30 m, come from the Chinese Academy of Sciences geospatial data cloud (http://www.gscloud.cn/search), and the research data interval is 5 years, as shown in Table 1.

Table 1 Landsat TM/OLI Satellite Imagery Information List

Landsat images	Data Number	Acquire date	Resolution	Cloud cover/%
Landsat5 TM	LT51220442005327BJC02	2005-11-23	30m	0.22
Landsat5 TM	LT51220442009034BKT01	2009-02-03	30m	0.17
Landsat8 OLI	LC81220442015291LGN01	2015-10-18	30m	0.58
Landsat8 OLI	LC81220442021003LGN00	2021-01-03	30m	2.88

2.3 Data Preprocessing

For the remote sensing image data of the Dongguan area, ENVI 5.6 software was used for pre-processing, including band superposition, radiometric calibration, atmospheric correction, image mosaic, and mask, to obtain the remote sensing image of the study area that meets the requirements. Based on this, Normalized Difference Vegetation Index (NDVI), vegetation coverage, and supervision classification were extracted.

In atmospheric correction, the FLAASH processing function was used to perform radiometric calibration on the four remote sensing images from 2005 to 2021, converting the brightness gray value of the images into absolute radiation brightness. Then the vector boundary of the study area was used to crop out the study area in the image.

III. METHODOLOGY

3.1 Method

This study is based on Landsat-5 and Landsat-8 remote sensing images of Dongguan city, and its main analysis steps (Figure 2) are as follows:

1. First, the images were classified into four categories: vegetation, construction land, bare land, and water bodies by Support Vector Machine (SVM) classification. Then calculate the areas of these four categories and their transfer matrix, which analyzes the spatio-temporal evolution characteristics of land use types.
2. Then, the image NDVI data was extracted, and the Dimidiate Pixel Model (DPM) was used to calculate the vegetation coverage, dividing their standard into five levels in this study area and calculating the transfer matrix of the five levels, which analyzed the spatio-temporal evolution characteristics of vegetation coverage.
3. Finally, the urbanization process of Dongguan city is represented by the change in construction land area, and the spatio-temporal evolution characteristics of vegetation coverage and urbanization expansion are analyzed by combining the urbanization process and the spatio-temporal evolution characteristics of vegetation coverage.

3.2 Support Vector Machine (SVM)

SVM classification is a kind of binary classification model that has many unique advantages in solving small sample, nonlinear, and high-dimensional pattern recognition problems. To date, SVM have been widely used to solve the problem of supervised classification of high-dimensional data, especially for high-dimensional feature space and large data volume problems such as hyper-spectral data.

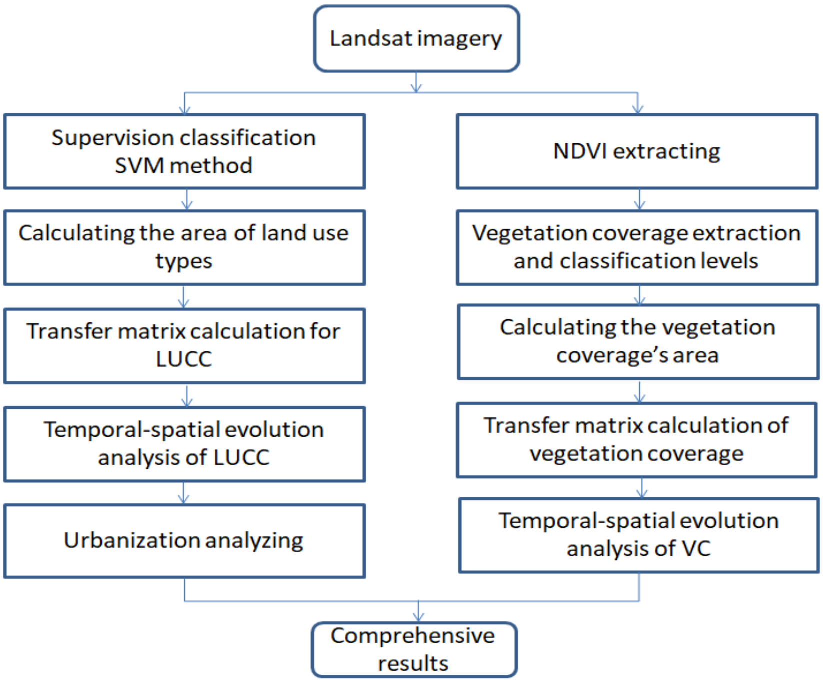

Fig.2 The Schema of This Study

The core idea of the SVM is based on the idea of structural risk minimization as the induction principle. By nonlinear mapping, the sample is projected to the high-dimensional feature space, constructing the optimal classification surface with the lowest VC (Vapnik Chervonenkis) dimension as possible in the high-dimensional space, which minimizes the upper bound of classification risk so that the classifier has the optimal generalization ability for unknown samples. Due to the fact that statistical learning theory has a complete theoretical system and solid mathematical foundation, and the vector holding machine generated by it has strong generalization ability, the theory and SVM have become a new research hotspot in the field of machine learning around the world. The main principles are as follows [2]:

If the vector x is linearly divisible in M-dimensional space, there is at least one hyperplane, dividing x into two types: -1 and 1, and then the hyperplane can be represented as shown in (1):

$$f(x) = w \cdot x + b \qquad (1)$$

Let the mark of xi be yi, if the classification is correct, as shown i n (2):

$$y_i(w \cdot x_i + b) \geq 1; i = 1,2,3 \cdots, N \qquad (2)$$

The minimum distance between the point closest to the hyperplane and the hyperplane is called the interval, which can be expressed as: 1/‖w‖, and the point is called the support vector. The sum of the minimum distance between two support vectors of different types and the hyperplane is 2/‖w‖, so finding the optimal hyperplane is to maximize the interval, which is minimized in the form, as shown in (3):

$$min \frac{1}{2} \|w\|^2 \qquad (3)$$

Through the constraints of equation (2), the expression of the optimization problem is obtained, as shown in (4):

$$minL(w, b, \alpha) = \frac{1}{2} \|w\|^2 - \sum_{i=1}^{N} \alpha_i [y_i(w \cdot x_i + b) - 1] \qquad (4)$$

After taking the partial derivative and setting it to 0, the constraint condition is obtained, as shown in (5):

$$\sum_{i=1}^{N} \alpha_i y_i = 0 \qquad (5)$$

Obtaining, as shown in (6):

$$w = \sum_{i=1}^{N} \alpha_i y_i x_i \qquad (6)$$

After equation s (5) and (6) are substituted into equations (4), the dual optimization problem is obtained, as shown in (7):

$$Q(\alpha) = \sum_{i=1}^{N} \alpha_i + \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} \alpha_i \alpha_j y_i y_j (x_i \cdot x_j) \quad (7)$$

Equation (7) can be solved by convex quadratic programming method, and the category decision function is finally obtained, as shown in (8):

$$f(x) = \sum_{i=1}^{N} \alpha_i y_i K(x_i \cdot x) + b \quad (8)$$

The above is a linear and nonlinear hard classification problem, and the position of the hyperplane is strictly fixed. Considering that a few points cannot be classified by hyperplane, by adding the relaxation variable ξ and the penalty factor C, equation (2) becomes:

$$y_i(wx_i + b) \geq 1 - \xi_i;\ i = 1,2,\cdots,N \quad (9)$$

Equation (3) becomes, as shown in (10):

$$min\frac{1}{2}\|w\|^2 + C\sum_{i=1}^{N} \xi_i \quad (10)$$

3.3 Normalized Difference Vegetation Index (NDVI)

Based on the NDVI calculation tool in ENVI 5.6 software, the NDVI was extracted from the pre-processed Landsat images covering the study area in four phases in 2005, 2009, 2015, and 2021. The calculation equation is as follows:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (11)$$

In equation (11), NIR is the reflectivity of the near infrared band (%), and RED is the reflectivity of the red band (%).

Statistical analysis indicates that the calculated NDVI value is not within the range [-1, 1], which is because remote sensing images are affected by aerosol, shadow, and other factors, and excessive atmospheric correction leads to overflow phenomena. It is therefore necessary to normalize the NDVI value, that is to say, remove outliers. The calculation equation is as follows:

$$(b1\ lt\ -1) * (-1) + (b1\ gt\ 1) * 1 + (b1\ ge\ -1\ and\ b1\ le\ 1) * b1 \quad (12)$$

In equation (12), "b1" is the NDVI value of the remote sensing image, "lt" is "less than", "ge" is "greater than or equal to", "le" is "less than or equal to", and "gt" is "greater than". After outlier processing, the gray scale images of the NDVI in each year of Dongguan City are finally obtained.

Some studies indicate that the NDVI value of the vegetated area is greater than zero, and the higher the vegetation coverage, the greater the NDVI value. On rocks, bare soil, and other surfaces, the reflectivity of visible light and near infrared is similar, and the NDVI value is about zero. On water vapor, clouds, snow, and other surface objects, the reflectivity of the visible light band is higher, and the NDVI value is usually less than zero. Therefore, NDVI is suitable for large-scale vegetation monitoring and has a good indicator [3].

3.4 Dimidiate Pixel Model (DPM)

Dimidiate Pixel Model (DPM) is a commonly used method to calculate the fraction of vegetation cover (FVC), which is one of the more widely used remote sensing estimation models. The model assumes that the ground area represented by each pixel is composed of two parts covered by vegetation and no vegetation, and the reflection spectrum information of ground objects received by the sensor is also formed by the superposition and combination of different reflection spectrum information from these two parts. The weight of reflected spectral information of objects in different places represents the proportion of objects in this pixel, so vegetation coverage can be used to represent the proportion of vegetation [4-6].

NDVI data were used to calculate the vegetation coverage, and NDVI values with cumulative frequencies of 95% and 5% were used as the two extreme values of NDVI to represent the $NDVI_{veg}$ value and $NDVI_{soil}$ value. When NDVI is less than $NDVI_{soil}$, the value of VFC is 0. When NDVI is greater than $NDVI_{veg}$, the value of VFC is 1. When the value of NDVI is greater than or equal to $NDVI_{soil}$ and less than or equal to $NDVI_{veg}$, that is to say, when it is between the $NDVI_{veg}$ value and $NDVI_{soil}$ value, calculate equation (13). Using DPM to estimate the vegetation coverage equation, the calculation equation is as follows:

$$(b1\ lt\ NDVI_{soil}) * 0 + (b1\ gtNDVI_{veg}) * 1 + (b1\ ge\ NDVI_{soil}\ and\ b1\ le\ NDVI_{veg}) * (b1 - NDVI_{soil})/(NDVI_{veg} - NDVI_{soil}) \quad (13)$$

In equation (13), $NDVI_{soil}$ is the NDVI value of bare land or non-vegetated area. $NDVI_{veg}$ is the NDVI value of the pixel in the area completely covered by vegetation.

3.5 Vegetation Coverage Classification

In order to better quantify the characteristics of vegetation coverage evolution, this paper divides the vegetation coverage in this study area into 5 grades according to 《the Classification and Grading Standard of Soil Erosion》 promulgated by the Ministry of Water Resources of the People's Republic of China in 2008. The criteria are as follows: <30% (low coverage), 30%-45% (medium to low coverage), 45%-60% (medium coverage), 60%-75% (medium to high coverage) and > 75% (high coverage).

3.6 Land Use Transfer Matrix

The main purpose of this paper is to study the relationship between vegetation coverage and urbanization expansion. Thus, according to the image of Dongguan, land use types are defined as vegetation, construction land, bare land, and water substances. Vegetation includes forestland, arable land, and grassland; construction land includes buildings, transportation facilities, and roads; bare land includes bare soil surface with less vegetation coverage, such as wasteland, abandoned arable, and quarry; and water substance includes lakes, reservoirs, sea areas, and wetlands. The change in construction land area indicates the urbanization process in Dongguan.

In this study, the land use transfer matrix is used for dynamic monitoring and analysis of land use, which can not only quantitatively and accurately indicate the transformation and change of different types of land use [7-9], but also quantitatively reveal the change rate of land transfer among different types of comprehensive land use transfer types. In other words, a two-dimensional matrix is obtained according to the change in land cover status at different times and phases in the same area, and the state and status of the system are described quantitatively [10-15]. The specific calculation equation is as follows:

$$P_{ij} = \frac{S_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{n} S_{ij}} \quad (13)$$

In equation (13), P_{ij} is the conversion probability of land use type i to land use type j; S_{ij} is the area of land use type i transformed into land use type j (km^2).

The land use transfer matrix model [11] is:

$$\begin{bmatrix} P_{11} & \cdots & P_{1j} \\ \vdots & \ddots & \vdots \\ P_{i1} & \cdots & P_{ij} \end{bmatrix} \quad (14)$$

IV. ANALYSES AND RESULT

4.1 Spatiotemporal Evolution of Vegetation Coverage

The analysis data indicate that the overall distribution of vegetation coverage in Dongguan is basically the same, showing the spatial distribution characteristics of "high in the east-low in the west -the lowest in the north" (Figure 3). The eastern part of the mountain is huge, concentrated into pieces with relatively large ups and downs, forming a very obvious high vegetation belt, including Xiegang town, Qingxi town, Huangjiang Town and other areas. Among them, Guanyin Mountain, Yinping Mountain, Dawang Mountain, Baoshan, Nanmen Mountain and other areas of the original forest are the main reasons for the formation of high vegetation areas. The distribution of middle, high and medium vegetation areas is relatively dispersed, mainly in the west and south, and the proportion of low vegetation areas is relatively large.

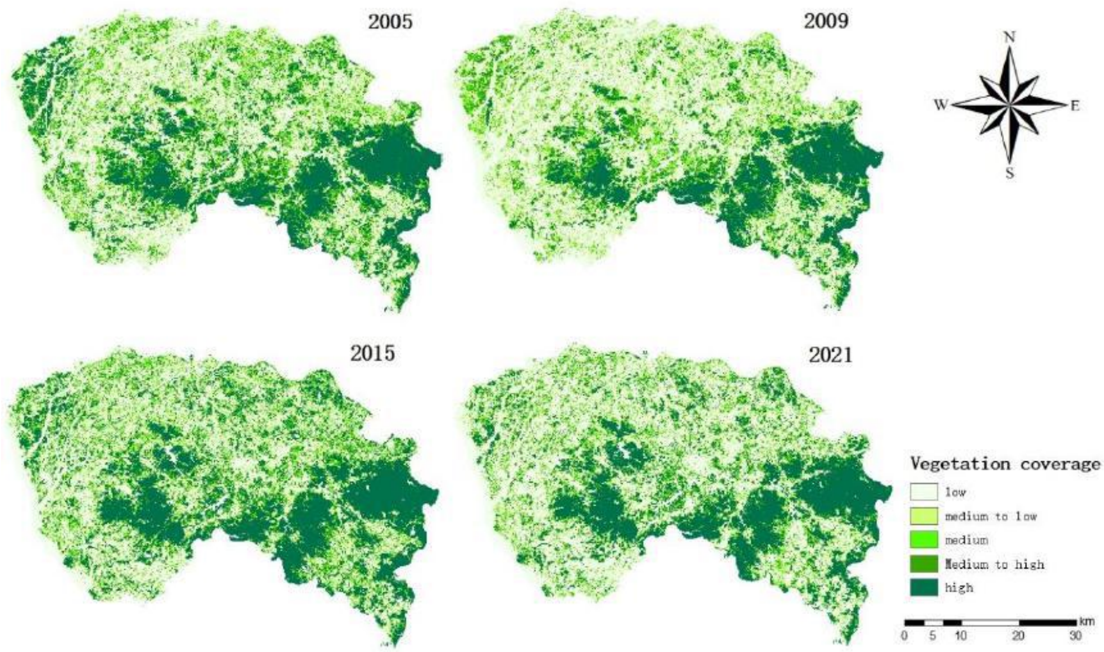

Fig.3 Vegetation Coverage Grade Map of Dongguan from 2005 to 2021

From 2005 to 2021, the area of low-vegetation area in Dongguan increased significantly, with an increase of about 92.14 km^2, and the area of high-vegetation area also increased, but the increase was relatively small, with an increase of about 13.36 km^2. Compared with 2005, the increased areas of high vegetation are mainly located in Huangjiang Town and Tangxia Town in the south in 2021, while the increased areas of low vegetation are located in the west and central north, as shown in Table 2.

Table 2 Grade of Vegetation Coverage in Dongguan from 2005 to 2021 (Unit: km^2)

Year	Low	Rate /%	Medium -low	Rate /%	Medium	Rate %	Medium -high	Rate /%	High	Rate /%
2005	993.98	40.53	311.28	12.69	261.20	10.65	249.60	10.13	637.70	26.00
2009	1152.70	47.00	352.58	14.35	249.62	10.13	210.31	8.58	489.60	19.94
2015	880.18	35.82	327.56	13.35	253.08	10.30	225.63	9.20	768.40	31.33
2021	1086.12	44.28	292.78	11.94	226.41	9.23	196.50	8.01	651.06	26.54

According to the distribution results of vegetation coverage in 2005 and 2021, the transfer matrix can be calculated, and the mutual transformation of vegetation coverage at all levels can be obtained by analyzing the transfer matrix.

In Dongguan, the area of medium and low vegetation transferred out was 247.35 km^2 in 2005, mainly to low and medium vegetation; in 2021, the area of low vegetation transferred in was 140.87 km^2, and the area of medium vegetation transferred in was 46.63 km^2. In 2005, the area of medium vegetation conversion was 218.03 km^2, which was converted to low and high vegetation in 2021. The area of low vegetation conversion was 83.88 km^2, and the area of high vegetation conversion was 51.51 km^2. In 2005, the area of mid-high vegetation transferred out was 209.54 km^2, and in 2021, the area of low and high vegetation transferred in was 56.95 km^2, while the area of high vegetation transferred in was 88.05 km^2. In 2005, the area of low vegetation conversion was 250.11 km^2. The area of high vegetation transfer was 179.39 km^2. In 2021, the area transferred from low to medium vegetation is 228.86 km^2, The transfer area of moderate vegetation is 218.03 km^2, The transfer area of medium to high vegetation is 156.44 km2, The area of low vegetation transfer in 2021 is 342.17 km^2, and the area transferred from high vegetation in 2021 is 193.70 km^2, as shown in Table 3.

The analysis shows that more vegetation has deteriorated from low-middle, middle, and middle-high vegetation to low vegetation, while less vegetation has improved from low-middle, middle, and middle-high vegetation to high vegetation since 2005. During the period from 2005 to 2021, the area of middle-low, middle, and middle-high vegetation decreased generally, while the area of low vegetation continued to increase with a relatively large increase and the area of high vegetation increased generally with a relatively small increase.

In general, the vegetation cover from 2005 to 2021 is decreasing, and the proportion of low vegetation cover areas is increasing, which may be related to human activities. For example, with the increase in population and the needs for economic and social development, cities continue to expand, arable land is converted into construction land, and arable land and forest land are reclaimed and developed, which results in the destruction and degradation of the original vegetation. On the other hand, climate change may lead to changes in precipitation and temperature, affecting vegetation growth. Drought, reduced water resources, and high temperatures may lead to the apoptosis and degradation of vegetation.

Table 3 Analysis of Transfer Matrix of Vegetation Coverage in Dongguan (Unit: km^2)

Year	Index	2021 year				
		Low	High	Medium	Medium-low	Medium-high
2005 year	Low	743.60	25.85	64.67	123.95	35.64
	High	60.47	457.18	37.53	31.64	49.76
	Medium	83.88	51.51	43.12	43.16	39.49
	Medium-low	140.87	28.29	46.63	63.88	31.56
	Medium-high	56.95	88.05	34.43	30.11	40.01

4.2 Spatiotemporal Evolution of Land Use Types

In terms of the overall distribution of land use types in Dongguan, vegetation dominates the south and east of the city (Figure 4), and water substance is divided into rivers, lakes, reservoirs, and some sea areas. Rivers are distributed in the northwest, including the Shima River and Dongjiang River, and lakes and reservoirs are scattered and distributed in areas with high terrain and vegetation coverage. The sea areas are mainly in the Lion Ocean and distributed in the west.

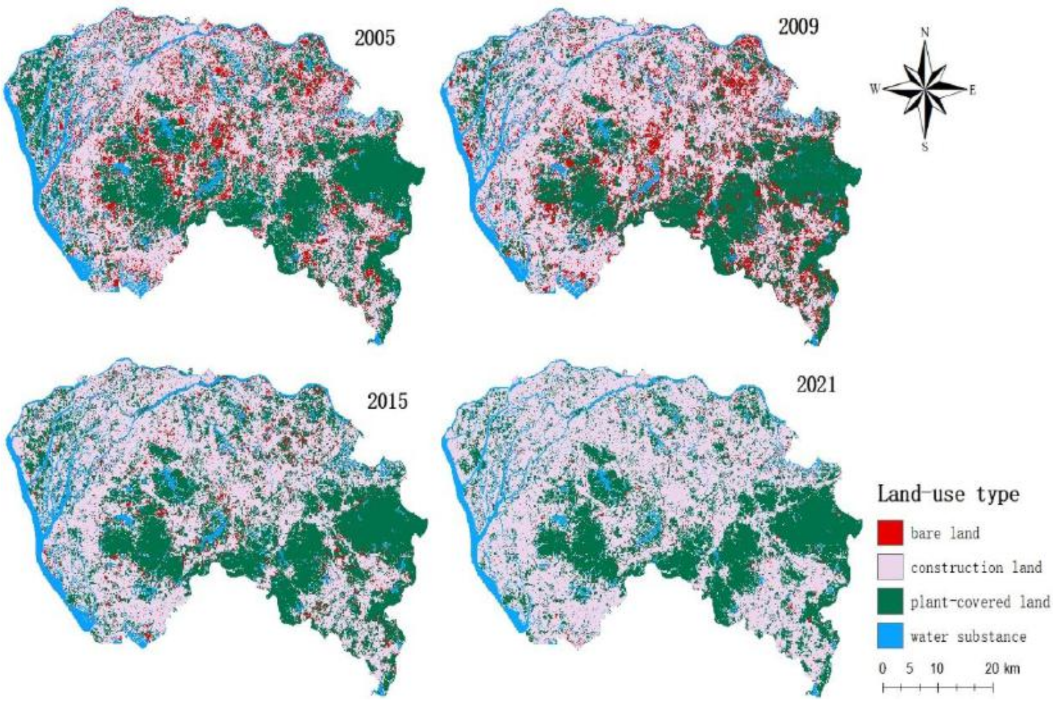

Fig.4 Distributions of Land Use Types in Dongguan from 2005 to 2021

According to the area changes of various types of land use (Figure 5), from 2005 to 2021, it can be seen that the area of construction land in Dongguan increased from 1092.43 km^2 to 1453.04 km^2, with a steady and large increase in area. And the increased built-up area is mainly bare land; the second is vegetation, which is mainly from arable land and forest land; and the last is water, which is mainly from wetlands.

During the period from 2005 to 2009, the vegetation area decreased significantly, and the built-up area and bare soil area continued to increase, indicating that sustained and intense urban construction activities were carried out during this period.

During 2009-2015, the vegetation area recovered somewhat, the increase rate of urban construction area slowed down, and the bare land area decreased, indicating that the urban construction activities in this period mainly used the original bare land, and the vegetation covered area recovered somewhat.

During the period from 2015 to 2021, the built-up area increased rapidly again, the bare land area continued to decrease, and the area covered by medium and low vegetation decreased, indicating that the urban expansion phenomenon of occupying arable and grassland appeared again.

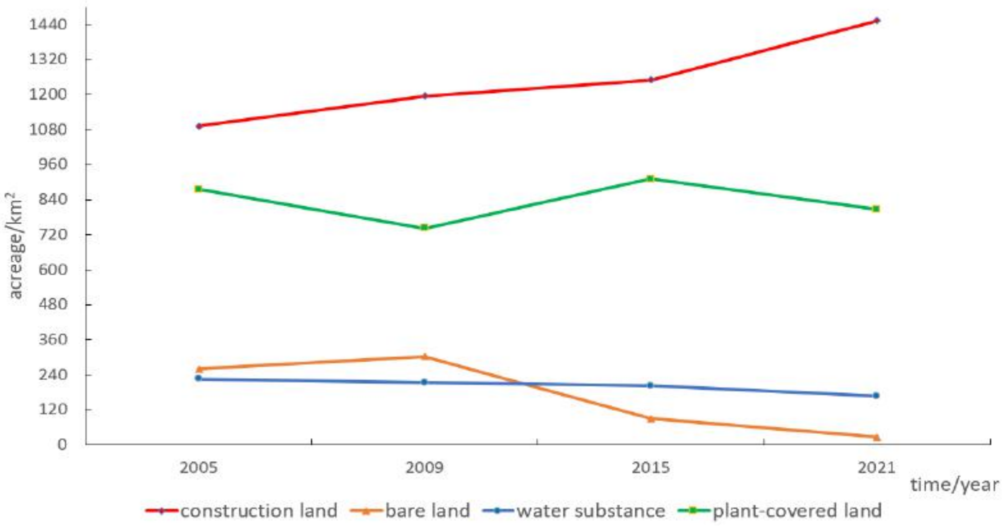

Fig.5 Area Changes of Land Use Types in Dongguan in Different Years

The land use status of Dongguan from 2005 to 2021 includes the area of bare land transferred out, which is 256.29 km^2, and the area converted into construction land, which is 222.87 km^2. The area of vegetation transferred out is 249.49 km^2, and the area converted to construction land is 233.63 km^2. Simultaneously, the area of water substance transferred out is 78.74 km^2, and the area converted into construction land is 62.71 km^2. The area of construction land transferred out is 159.64 km^2.

In addition, in 2021, the bare land transfer area was 21.94 km^2, the vegetation transfer area was 183.18 km^2, the water transfer area was 18.84 km^2, and the construction land transfer area was 519.21 km^2, as shown in Table 4. Among them, bare land has the largest net change, followed by vegetation and water bodies. The shift from bare land to construction land is the most obvious feature of the urbanization process. The shift of vegetation towards construction land reflects the process of urban construction at the cost of occupying agricultural land and logging forest land. The diversion of water bodies towards construction land mainly extends to wetlands, lakes, and other water bodies through land reclamation.

Table 4 Transfer Matrix of Land Use Types in Dongguan (Unit: km^2)

Year	Index	2021 year			
		Construction land	Bare land	Water substance	Vegetation
2005 year	Construction land	933.68	8.13	12.85	137.66
	Bare land	222.87	4.12	1.07	32.35
	Water substance	62.71	2.7	147.42	13.17
	Vegetation	233.63	10.93	4.93	623.79

4.3 Correlation Analysis of Vegetation Coverage and Urbanization

Objectively, there is a close relationship between urbanization and the ecological environment. Due to the transfer of rural populations to cities and the continuous expansion of urban areas, land resources in natural ecological space must be occupied, resulting in changes in vegetation and the ecological environment, which puts forward higher requirements for urban environmental protection. Simultaneously, the increase in economic aggregate makes cities more capable of environmental protection investment and protects vegetation resources to a certain extent. Therefore, urbanization has a dual effect on vegetation resources.

According to the vegetation coverage transfer matrix analysis, during the period from 2005 to 2009, the area of low vegetation and middle and low vegetation continued to increase, mainly from medium vegetation to low vegetation and high vegetation. The area transferred by low vegetation was 65.85 km^2, and the area transferred by high vegetation was 75.70 km^2. In this stage, the area of construction land and bare land continued to increase, and the area covered by vegetation continued to decrease, indicating that human beings carried out continuous and intense urban construction activities at the cost of destroying vegetation during this period, and the urbanization process increased significantly, resulting in an increase in the area of low-vegetation areas, that is to say, construction land and bare land.

During the period from 2009 to 2015, the area of high vegetation and middle and high vegetation continued to increase, from low vegetation and middle and low vegetation to middle and high vegetation, and the total area of middle and high vegetation transferred was 119.55 km^2, and the total area of high vegetation transferred was 112.67 km^2. At this stage, with the destruction of the ecological environment and the deterioration of the city's internal environment, Dongguan's economic development was affected. In the meantime, human beings realized the impact of the environmental destruction and began to restore the ecological environment, so that the vegetation area recovered somewhat, the increase rate of urban construction area slowed down, and the urbanization process slowed down. In this period, urban construction activities mainly used the original bare land; the bare land area was greatly reduced, and the vegetation coverage area was restored.

During the period from 2015 to 2021, the area of low vegetation and high vegetation continued to increase, due to the transformation of middle and low vegetation into low vegetation and the area of low vegetation into 162.48 km^2. During this period, the built-up area increased rapidly again, the bare land area continued to decrease, the middle and low vegetation areas decreased, but the high vegetation areas increased, indicating that population growth required greater space and resources, and the urban expansion phenomenon of occupying arable and grassland again appeared. However, during this period, Dongguan implemented many policies, such as returning arable to forest, protecting natural forests, adjusting industrial structure, and developing tourism such as ecological parks, which should also pay attention to the protection of the ecological environment and reduce the destruction of forest land in some natural ecological areas.

In summary, the urbanization level of Dongguan can be used as one of the reference factors for the change of vegetation coverage, but the level of urbanization cannot be used as an absolute influencing factor to measure the change of urban vegetation coverage, and comprehensive analysis should be carried out in combination with other influencing factors.

V. CONCLUSION

In this study, the DPM and transfer matrix were used to estimate the vegetation coverage of Dongguan, analyzing the area proportion and change of vegetation coverage area at all levels. Meanwhile, the transfer matrix method of vegetation coverage can effectively analyze the mutual transformation of vegetation coverage area in each year. Moreover, by analyzing the change trend of land type area and the transfer matrix of each land type, the change index of construction land area was compared with the change degree of vegetation coverage, analyzing correlation between the change degree of vegetation coverage and urbanization expansion.

This study provides a new way of thinking about the spatio-temporal evolution characteristics of vegetation coverage in the past 15 years and the interannual variation law of vegetation coverage, which can also provide a decision-making basis for ecological environment construction in Dongguan. The main conclusions are as follows:

(1) The overall distribution of vegetation coverage in Dongguan is basically the same, showing the spatial distribution characteristics of "high in the east-low in the west-the lowest in the north".

(2) During the period from 2005 to 2021, the coverage area of middle-low, middle and middle-high vegetation will decrease overall, while the coverage area of low vegetation will continue to increase with a relatively large increase, and the coverage area of high vegetation will increase with a relatively small increase.

(3) During the period from 2005 to 2021, the area of construction land in Dongguan will increase steadily and greatly, and the increased built-up area is mainly bare land, followed by vegetation and water area.

(4) Through the combined analysis of the change trend of vegetation coverage and land type area at all levels from 2005 to 2021, which indicates that the spatial-temporal evolution characteristics of vegetation coverage in Dongguan are closely related to urbanization expansion. On the one hand, urbanization will destroy vegetation in various ways. For example, urbanization increases the area of construction land, leading to the loss of arable land and forest land. On the other hand, with the acceleration of urbanization, the state will also implement various measures to protect the ecological environment, such as returning arable to forest, adjusting industrial structure, and developing some tourism to protect forest land.

Finally, this study only selected urbanization and vegetation coverage at all levels for comparative analysis, and did not consider other natural and social factors, such as natural disasters, population density, urban economic development and other factors, which would also have an impact on vegetation coverage. Therefore, the subsequent research will also incorporate these factors affecting the vegetation coverage into the decision-making of the analysis.

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Effect of Shade and Thinning on Yield and Chemical Content of Tomato (*Lycopersicum esculentum* Mill.)

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***Abstract*— *Tomatoes are one of horticultural commodities which have many benefits for the community, including spices, fruits and vegetables. Tomato cultivation techniques using fruit shade and thinning can be done to overcome the constraints of the mismatch between the quality of products produced by farmers and the quality of products desired by community. Shade has a function to create environmental conditions in accordance with plant conditions, while fruit thinning has a function to maximize the results of photosynthesis so that it can improve the quality of tomatoes. This study aimed to determine the effect of shade and thinning on the result and quality of tomatoes. The study was conducted from January to May 2022 in the Malang, East Java. This research used a Completely Randomized Design with Nested Pattern which consisted of 12 treatments with 3 replications, so that from 36 units of combination treatment. The treatment used was a combination of the use of fruit shade (0,25 and 50%) and thinning intensity (0,3,4 and 5). The analysis of the data used was the F level test of 5%. If the 5% F test had a significant effect, then it was followed by a 5% HSD test. The results showed that the use of fruit shade and thinning significantly affectd the parameters of flower emergence, fruit weight per hectare, fruit weight per fruit, fruit volume, fruit diameter, and no significant effect on the parameters of total dissolved solids.*

***Keywords*— Acid–base Titration, Total Dissolved Solids, Light Intensity.**

I. INTRODUCTION

Tomato is one of the plants which classified as a horticultural commodity that has many benefits. It does not only function as a fruit vegetable but is often used as a spice in cooking, food and drinks. Tomato plants are cultivated by farmers to meet the needs of consumers and industry. The need for tomato consumption in 2015 reached 4.18 kg per capita and increased in 2016 to 4.46 kg per capita. To meet the increasing needs of tomatoes, it must be followed by the production of good quality tomatoes in accordance with market needs (Statistics Indonesia 2017).

The obstacles faced by farmers to meet the needs of consumers are in the mismatch between the quality required by consumers and the quality of products produced by farmers. The efforts which can be made to improve the quality of plants are to create environmental conditions in accordance with plant growth and pay attention to plant cultivation techniques.

One of the cultivation techniques which can be used for environmental engineering is the use of shade. The use of shade is done because it provides benefits to regulate the intensity of solar radiation, temperatures, and humidity. Even though tomatoes are quite tolerant, but the intensity Low sunlight can affect photosynthesis. Process disrupted photosynthesis will cause tomatoes to be produced has a lower weight than it should (Haque et al. 2009), but research on low light intensity on quality tomatoes are still not much done. Therefore, it needs more study more about the effect of shade on the production and quality of tomatoes necessary. Plants try to increase light absorption in light deficit conditions by increasing the amount of chlorophyll per unit leaf (Cabuslay et al. 1995). Decreased ratio of chlorophyll a / b in plants shade tolerant aims to improve efficiency capturing light for the plant as a whole (El-Abd et al. 1994).

Another effort which can be done to improve fruit quality is by conducting fruit thinning. Reducing the number of fruits can increase fruit weight per fruit. It is intended to reduce competition for the use of photosynthesis between fruit and flowers, so that photosynthesis can be concentrated for fruit development. Based on the description above, the research which uses the fruit shade and thinning needs to be done to determine the result and quality of tomatoes. The purpose of this study was to determine the effect of shade and thinning on yield and chemical content of tomatoes.

II. MATERIALS AND METHODS

The research had been carried out in Sidorahayu Village, Wagir Sub-District, Malang Regency for 5 months with the implementation period of January-May 2022. The tools used are pot tray, paranet, bamboo, luxmeter, refractometer, calipers, analytic scales, measuring cups, rulers or meters sprayer, stationery, and camera. While the materials used are variety tomato seeds of Tymoty, soil, goat manure, water, poly bag size 35 cm x 35 cm and raffia rope. Fertilizers used include SP36 fertilizer, Urea fertilizer, NaCl fertilizer, and ZA fertilizer.

The research method used is a Completely Randomized Design with a Nested Pattern (using nested) using 12 treatments including N0B0 (without shade + without thinning), N0B1 (without shade + maintained 3 fruits), N0B2 (without shade + maintained 4 fruits), N0B3 (without shade + maintained 5 fruits), N1B0 (shade of 25% + without thinning), N1B1 (shade of 25% + maintained 3 fruits), N1B2 (shade of 25% + maintained 4 fruits), N1B3 (shade of 25% + maintained 5 fruits), N2B0 (shade of 50% + without thinning), N2B1 (shade of 50% + maintained 3 fruits), N2B2 (shade of 50% + maintained 4 fruits), N2B3 (shade of 50% + maintained 5 fruits). Each treatment is repeated 3 times, so that 36 units are obtained. Each experimental unit consists of 6 plants, so that a total plant of 216 plants is obtained.

Parameters of observations: The variables observed by using non-destructive methods included the time flowers appeared, while the observed variables include fruit weight per plant , fruit weight per fruit, fruit volume, fruit diameter, total dissolved solids and Acid–base titration.

Statistical analysis: Data obtained from observations are analyzed using ANOVA F test with a level of 5%. If the results of the analysis of variance have a effect, then continued with Significant Difference test (HSD) at the level of 5% (Gomez and Gomez 1984).

III. RESULT AND DISCUSSION

Time of Flowers Appear, Fruit Weight per Plant and Fruit Volume and Diameter

The results of the variety analysis show that the treatment of fruit shade and thinning gave a significant effect on the time of flower appearance on tomato plants. Based on Table 1, it can be seen that in the treatment without shade and shade of 25% with all thinning rates produce the fastest flowering time, while in the shade treatment of 50% with all thinning results has the lowest flowering time.

The results of the analysis of variance show that the treatment of fruit shade and thinning gives a significant effect on the weight of fruit per plant. Table 1 shows that tomato plants without shade are able to produce the highest average fruit weights per plant. The average of fruit weight per plant in the treatment without shade and without thinning are not significantly different from the treatment of shade 25% with all thinning levels.

The results of the analysis of variance show that the treatments of fruit shade and thinning give a significant effect on the fruit weight per fruit. Table 1 shows the condition of plants without shade and shade of 25% shows that tomato plants are able to produce the highest average tomato compared to shade of 50%. The results of the research show that the treatment without tomato thinning gave the highest average fruit weight per plant compared to other treatments.

The results show that the use of fruit shade and thinning has a significant effect on the parameters of fruit volume and diameter. Table 1 shows that the treatment without shade maintained by 3 fruits per bunch gives the highest fruit volume and diameter, whereas at shade of 50% treatment with all fruit thinning levels produced the lowest average fruit volume and diameter. The results also show that the combination of treatments with the treatment maintained 3 fruits per bunch produces the highest fruit weight, while the treatment without thinning produces the lowest fruit weight.

Total Dissolved Solids (TDS) and Acid–base Titration of Tomatoes

The observations showed that total dissolved solids (TDS) of tomatoes in the shade difference and the amount of thinning were 3.72 to 4.04 (Figure 1). Whereas the results of acid-base titration show that the greater the shade, the lower the content of acid-base Titration (Figure 2). In tomatoes without shade, the results of Acid-base Titration 302.2 mg $100g^{-1}$ can be seen while in the shade of 50% it can go down to 229.8 mg $100g^{-1}$.

The data shows that the higher the shade level, the Acid-base Titration will be lower. Figure 3 shows that the R^2 score of 0.9433 besides the equation shows the existence of a negative correlation.

Table 1. Comparison of SM, pH, TOC, TN, P and K in five different soil types.

Treatment	Time of Flower Appearance (DAP)	Fruit Weight per Plant (g)	Fruit Weight per Fruit (g)	Fruits Volume (cc)	Fruits Diameter (mm)
N0B0	32.33 a	830.72 b	38.25 c	48.89 def	44.10 bc
N0B1	32.33 a	692.55 b	40.67 c	58.30 g	46.84 c
N0B2	32.00 a	786.33 b	36.28 bc	51.55 efg	44.76 c
N0B3	32.33 a	773.44 b	35.19 abc	47.78 cdef	43.26 bc
N1B0	32.33 a	650.66 b	32.38 abc	48.88 def	43.64 bc
N1B1	32.00 a	628.52 b	38.40 c	55.53 fg	45.24 c
N1B2	32.33 a	629.16 b	38.59 c	49.88 defg	44.31 bc
N1B3	32.67 a	688.33 b	36.65 bc	46.11 bcde	43.21 bc
N2B0	37.00 b	188.88 a	23.68 a	41.85 abcd	38.08 a
N2B1	40.33 b	137.36 a	25.98 ab	39.26 abc	40.51 ab
N2B2	37.67 b	220.95 a	25.11 ab	37.03 ab	38.70 a
N2B3	38.67 b	170.67 a	25.58 ab	34.07 a	38.04 a
HSD (5%)	3.92	303.23	11.72	9.19	4.11
CV (%)	3.99	19.32	12.04	6.70	3.28

Note: The numbers accompanied by the same letter in the same column show that there is no significant difference based on the 5% HSD test, DAP = days after planting

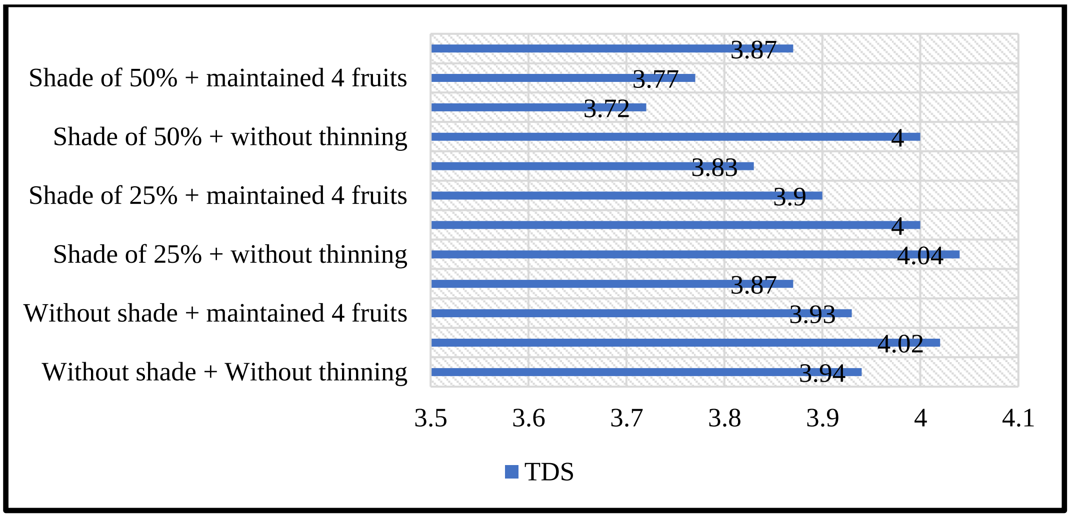

Fig.1. Total Dissolved Solids (TDS) of Tomatoes

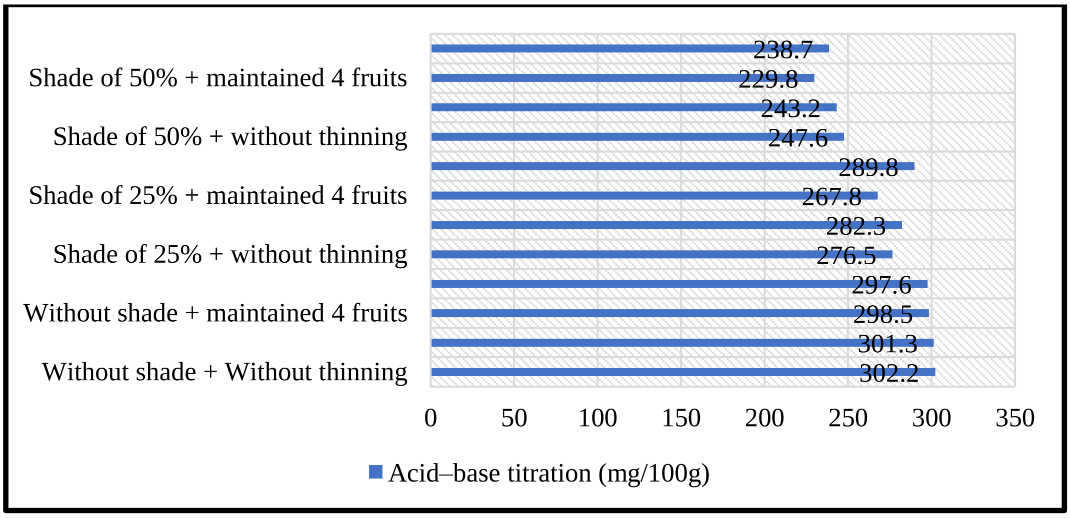

Fig.2. Acid–base Titration of Tomatoes

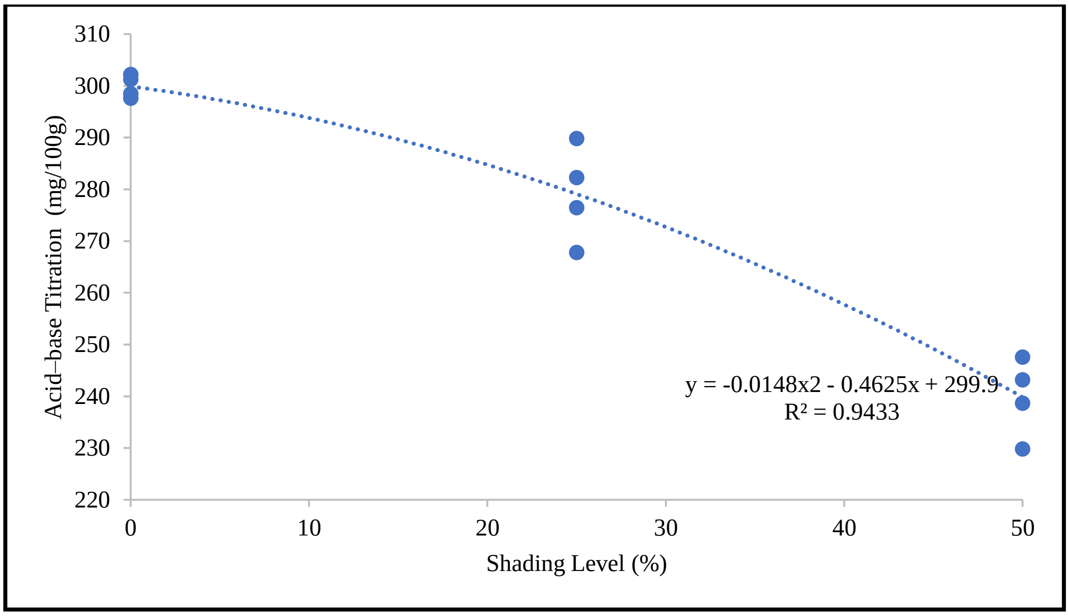

Fig.3. Regression Between the Percentage of Shade and Content of Acid-base Titration on Tomatoes

IV. DISCUSSIONS

Time of Flowers Appear, Fruit Weight per Plant and Fruit Volume and Diameter

The results show that the higher the shade level can slow down the time of flower appearance. This happens because the shade can cause low light intensity, so it can cause tomato plants to have flowers more slowly. According to Kittas et al. (2009) the quality of solar radiation at a higher level of shade was not suitable for the flowering induction process, so that the appearance of flowers on tomato plants under shade was longer. This relates to the presence of phytochromes in plants which become the pigments and responsive to flowering. Sirait (2008) added that sunlight had a very important function in the process of photosynthesis in plants which affected growth

The results showed that the treatment without shade and 25% shade resulted in fruit weights that were not significantly different. This makes it possible that tomato plants are able to survive and are able to produce optimally even in shade treatment. This is supported by the research of Kartika et al. (2015), who state that tomato plants can grow well in the shade below 30%, where the shade under 30% is the optimal condition because it gets low sun intensity and low temperatures accordingly, so that photosynthetic activity runs optimally and causes assimilation which is needed by plants to meet maximum growth. Besides, fruit thinning also affects the weight of fruit per plant.

Thinning tomatoes is an action taken to reduce the number of fruits per bunch of tomatoes. It is intended that the rate of assimilation of photosynthesis results can be focused on several fruits so as to improve the quality of tomatoes. However, fruit thinning can reduce the average fruit weight per plant. The more fruit that is maintained per fruit bunch, the more fruit weight produced per plant, otherwise the less fruit that is maintained per fruit bunch, the less fruit weight produced per plant. This is in accordance with the research conducted by Rahayu et al. (2011) who state that the smaller number of melons maintained, it can increase the weight per fruit but reduce the production of weights per plant. According to Sugihartiningsih and Wartapa (2008), explain that one of the activities carried out at the main branch aims to give higher result of photosynthesis for the establishment and development of tomato fruit.

The result show that the 50% shade condition on tomato indicate that the plants do not carry out photosynthesis optimally, so they are not able to form the optimal volume and diameter of the fruit. Treatment without shade and shade of 25% of tomato plants are able to form the optimal fruit weight. This happens because each plant requires optimal conditions to form tomatoes. This is in accordance with the research of Sanura (2013), which resulted that the shade of 25% treatment gave the highest results of weight per tomato. Besides, thinning fruit also affects the weight of fruit per fruit. The results show that the combination of treatments with the treatment maintained 3 fruits per bunch produces the highest fruit weight, while the treatment without thinning produces the lowest fruit weight. This happens because in the treatment without thinning, the number of tomatoes kept per plant will increase, so that the assimilation results of photosynthesis can not focus on enlargement of several fruits but split into many tomatoes, so as to reduce the weight of fruit per tomato. This is consistent with the results of research by Hapsari et al. (2017), who stated that the less fruit exists, the greater the volume and weight of fruit per fruit unit. Shehata et al. (2013), too states that tomatoes are planted on condition the shade of 35% and 65% shows an increase plant height, stem diameter, number of branches and interest, and total crop yields.

The treatment combination without shade and maintained 3 per bunch are able to provide conditions optimally for fruit development. The condition without shade plant gets full sunlight intensity, causing the plants to perform photosynthesis optimally. Syakur (2012), added that during the day the sun's rays are blocked by shade, this can result to reduce solar radiation in reaching the ground. Photosynthesis can optimally improve the quality of tomatoes through enlargement of the volume and diameter of the fruit. Suparwata (2018), added that in the cultivation of agricultural crops, the presence of shade greatly affects the intensity of radiation. So that besides directly affecting plants, it also has an indirect effect through changes in the microclimate around plants. Formation of fruit volume and diameter can be affected by thinning tomatoes.

Thinning fruit can increase the volume and diameter of the fruit, because with the reduction in the number of fruit kept the allocation of photosynthesis can focus only on the fruit maintained. Research conducted by Angelia (2017) states that the number of fruits per plant maintained can affect the fruit circumference and fruit volume. The more fruit kept, the smaller the weight, circumference and volume of the fruit.

Total Dissolved Solids (TDS) and Acid–base Titration of Tomatoes

TDS shows that the shade treatment and fruit thinning do not affect the formation of total dissolved solids. This is not in accordance with the opinion of Sandri et al. (2013) who stated that the total value of dissolved solids will decrease with increasing shade levels. This is presumably because light is an energy source for photosynthesis so that it can increase the total dissolved solids of the fruit. The higher the fruit acid, the less brix is contained therein. The increasing of brix value shows that the sugar content in the fruit is increasing. Callejón-Ferre et al. (2009) stated that the total dissolved content of tomatoes is reduced by the shade increased, a significant difference was seen in the shade of 60% which decreased from the minimum shade limit of 50%.

Yue et al. (2008) states that titrated acidity is negatively correlated with relative light intensity. This means that fruit acid content increases as light intensity decreases. The study is different from the results which is obtained. This is thought to be due to the effect of high temperatures on 75% shade. According to Gent (2007) a decrease in the content of fruit acid titrated tomatoes occur with increasing temperature.

V. CONCLUSIONS

Based on the results of the research, it can be concluded that the quality of tomatoes which can be affected by the shade treatment and thinning of fruit is fruit weight, fruit volume, and fruit diameter. The higher the intensity of the shade and the more fruits retained per fruit bunch can reduce the average fruit weight per plant, fruit weight per fruit, fruit diameter and fruit volume. High quality tomatoes can be seen from tomatoes which have fruit weight and chemical content.

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Effect of Using Different Levels of Ginger (*Zingiber Officinale Roscoe*) Extract on The Quality Characteristics of Camel's Sausage

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Abstract— *The objective of the current study was to evaluate the effect of adding different levels of ginger extract in the formulation of camel sausage. Four treatments were investigated: T1 control and the other treatments (T2, T3 and T4) were treated with 5, 10, and 15 % ginger extract (v/w). Chemical, physical, sensory properties and histological examination were evaluated. Sausages treated with ginger extract had higher moisture, lower fat content and no significant differences in protein content. Collagen content was significantly increased in treated cooked sausages. Fat and moisture retention significantly increased in camel sausage treated with ginger extract. The addition of ginger extract significantly improved the color and shrinkage measurements. A Light micrograph of camel sausage treated with 10% ginger extract exhibited severely broken muscle fibers and severely destructed connective tissue. Sausage treated with 10% ginger extract recorded the highest score for texture, tenderness and overall acceptability.*

***Keywords*— Camel sausage. Ginger extract. Quality characteristics.**

I. INTRODUCTION

Camel is an important source of meat production in Asia and Africa, especially in Arab countries. The high demand for camel meat may be due to its characteristics which make this meat a superior and healthier meat compared with other red meats (Abdel-Naeem et al. 2022). The low-fat content with high polyunsaturated fatty acids, low cholesterol, high proportion of proteins with high essential amino acids, High moisture content, and vitamins (Abdel-Naeem & Mohamed 2016). Furthermore, camel meat had the lowest microbial counts and zero pathogenic bacteria (Mohammed et al, 2020). Even though the fact that camel meat may be considered an excellent raw material for meat products processing (Farouk & Bekhit, 2013). The high content of connective tissue makes this meat the tough kind of meat and a challenging raw material for meat processors for processing acceptable meat products (Kadim et al., 2008). Therefore, different methods have been devised to increase the tenderness of camel meat to be suitable for further processing of different products. There are various conventional methods for meat tenderization such as chemical and mechanical methods (Verma et al, 2019). Recently, biological methods including proteolytic enzymes are becoming a popular method for meat tenderization. Lastly, proteolytic enzyme derived from plant sources has become an increasing focus of interest among food processors and meat technologists (Fernández-Lucas et al, 2017).

Proteolytic enzymes derived from ginger (*Zingiber officinale Roscoe*) were introduced as effective enzymes for tenderizing tough camel meat and other meat types (Mendiratta et al, 2010). Zingibain is a thiol proteinase extracted from ginger. It has optimal enzymatic activity at 60 °C and pH 5.5. Moreover, the proteolytic activity of zingibain is more effective on collagen than actomyosin (Thompson et al., 1973).

Most of the previous studies investigated the impact of using proteolytic enzymes on the tenderization of raw meat, However, the effect of incorporating these enzymes in the formulation of meat products for improving the quality characteristics of this meat as raw material is limited. Therefore, the current study aimed to study the effect of using different levels of ginger extract as a tenderizing agent in the formulation of camel sausage to improve the quality characteristics of the product.

II. MATERIALS AND METHODS

2.1. Preparation of camel sausage

Fresh camel meat and hump fat of ~ 5 years old Arabian one-humped camels (*Camelus dromedarius*) were obtained from a slaughterhouse (Cairo, Egypt) and transported to the laboratory for sausage processing. Camel meat and hump fat were separately ground through a 3- 4 mm plat meat grinder (K.R.SU: KMG1700. China). The following ingredients 65% lean camel meat, 20 % hump fat, 1.5% sodium chloride, 10% water, 3% starch, and 0.5% seasonings mix were used for sausage processing. The ground meat and fat were mixed with water, salt, starch, and seasonings. The mixture was divided into four treatment groups: (T1) Control group and the other treatments (T2, T3 and T4) were treated with 5, 10, and 15 % ginger extract (v/w). Three replicates for each sausage formula were processed. The mixture was transferred to a manual sausage maker and stuffed into natural casings. The sausage was tiered into 10-12 cm lengths and placed in plastic foam trays, packed in polyethylene bags and frozen at -20 ºC ±2 until further analysis.

2.2. Chemical analysis

2.2.1. Proximate composition

Proximate composition and collage content of raw and cooked camel sausage were determined by using the Food Scan™ Pro meat analyzer (Foss Analytical A/S, Model 78810, Denmark). The average of results was calculated from three replicates of each treatment.

2.2.2. Fat retention and moisture retention (%)

Fat retention of camel sausage was determined according to Murphy et al. (1975).

$$\text{Fat retention (\%)} = \frac{(\text{Cooked sample weight}) \times (\text{\% Fat in cooked sample})}{(\text{Raw sample weight}) \times (\text{\% Fat in raw sample})} \times 100$$

Moisture retention was determined according to El-Magoli et al. (1996).

$$\text{Moisture retention (\%)} = (\text{Cooking yield \%} \times \text{Moisture \% in cooked sample})/100$$

2.3. Physical analysis

2.3.1. pH value

pH values of raw camel sausage were determined by using a digital pH meter (Jenway 3320 conductivity and pH meter, England) as described by Khalil (2000).

2.3.2. Cooking measurements

Camel sausages were cooked in a preheated oven for 30 min. All cooking measurements were determined as described by Naveena et al. (2006) as follows:

$$\text{Cooking loss (\%)} = \frac{(\text{Uncooked sample weight}) - (\text{Cooked sample weight})}{(\text{Uncooked sample weight})} \times 100$$

$$\text{Cooking yield (\%)} = \frac{(\text{Cooked sample weight})}{(\text{Uncooked sample weight})} \times 100$$

2.3.3. Shear force value

The shear force value of each cooked camel sausage was determined by using Instron Universal Testing Machine (Model 2519-105, USA) three times at different positions. The average shear force was calculated from the three obtained results (Kg/f).

2.3.4. Shrinkage measurements

Raw and cooked camel sausages were measured for shrinkage measurements as described by Berry (1993) using the following equation:

$$\text{Reduction in width (\%)} = \frac{(\text{Uncooked sample width}) - (\text{Cooked sample width})}{(\text{Uncooked sample width})} \times 100$$

$$\text{Reduction in length (\%)} = \frac{(\text{Uncooked sample length}) - (\text{Cooked sample length})}{(\text{Uncooked sample length})} \times 100$$

Shrinkage (%): Dimensional shrinkage was calculated using the following equation as reported by Murphy et al. (1975)

$$= \frac{(\text{Raw length} - \text{Cooked length}) + (\text{Raw width} - \text{Cooked width})}{(\text{Raw length} + \text{Raw width})} \times 100$$

Color measurements

Color parameters (L*, a* and b*) of raw camel sausage were measured according to CIE (1976) by using a Chroma meter (Konica Minolta, model CR 410, Japan). The color was expressed as Lightness (L* value), redness (a* value) and yellowness (b* value).

2.4. Histological examination

Raw camel sausage samples (1 × 1 cm) were fixed for 24 h in 10% formalin and then, washed with running water. Fixed camel sausages were dehydrated in different concentrations of ethyl alcohol, followed by cleaning in xylene, and embedded in paraffin at 56 °C in a hot air oven for 24 h. Paraffin blocks were sectioned at 4–6 µm thickness, and stained with Haematoxylin and Eosin as reported by Banchroft et al. (1996).

2.5. Sensory Evaluation

Cooked camel sausage was subjected to organoleptic evaluation and scored appearance, texture, juiciness, flavor, tenderness and overall acceptability using a 9- point hedonic scale as described by A. M. S. A. (1995). The mean scores of the obtained results of the organoleptic evaluation were then statistically analyzed.

2.6. Statistical analysis

All data were analyzed using the statistical analysis system SAS (2000).

III. RESULTS AND DISCUSSION

3.1. Chemical composition

Results of the chemical composition and collagen content of raw and cooked camel sausages treated with different levels of ginger extract are shown in Table 1. Raw sausages treated with 5% ginger extract had the higher moisture content, followed by sausages treated with 15%, 10% ginger extract and the control group with non-significant ($p<0.05$) change. No significant differences were found in protein content among sausage treatments. Raw sausage treated with 5% ginger extract showed the lowest fat content followed by sausages treated with 10 and 15 %, while sausage of the control group had the highest fat content. Collagen content was higher in the control group than in sausages treated with different levels of ginger extract. However, cooked sausages exhibited a reduction with non-significant differences in moisture content. The control group had the higher protein content, while sausages with ginger extract showed the highest fat content Regard to collagen content, the raw sausage of the control group had a higher content than sausages treated with ginger extract. Contrarily, a significant increase was found in collagen content in cooked sausages treated with ginger extract. These results are consistent with Abdel-Naeem & Mohamed (2016) who found that raw camel burgers treated with 7% ginger extract significantly increased the moisture content and decreased fat content with non-significant changes in protein content. Karpinska-Tymoszczyk et al. (2022) stated that moisture content was higher in meatloaf treated with different levels of ginger extract, no significant differences were found in protein content with a non-significant increase in fat content. Conversely, Abdeldaiem & Ali (2014) indicated that the addition of different levels of ginger extract as a tenderization agent in camel meat had no significant effect on the proximate composition. However, the resultant higher moisture content in ginger-treated sausages indicates an improvement in the hydrophilic characteristics. Meanwhile, the reduction in protein content may be due to the degradation of protein by proteolytic enzymes resulting in the release of free amino acids and peptides (Abdel-Naeem & Mohamed, 2016). Results of collagen content are inconsistent with Abdeldaiem & Ali (2014) who found that the addition of different levels of the ginger extract significantly increased the collagen content. Similar results were found by Abdel-Naeem et al. (2022).

3.2. Physical properties

3.2.1. pH value

Results of pH values of camel sausage treated with different levels of ginger extract are shown in Table 2. No significant differences were found in pH values of treated sausages with ginger extract and the control group. These results are close to that obtained by Abdel-Naeem & Mohamed (2016) they found that slight non-significant differences were found in camel patties treated with 7% ginger extract. Also, Abdel-Naeem et al. (2022) found that a slight decrease was found in camel meat treated with 7% ginger extract and 5% ginger + 0.5% papain. Also, Abdeldaiem & Ali (2014) postulated that no significant differences were found in pH values of camel meat treated with different levels of ginger extract. On the other hand, Karpinska-Tymoszczyk et al. (2022) demonstrated that the pH values of meatloaves treated with ginger were higher than the control sample, but these differences were not significant.

3.2.2. Shear force

Sausages treated with different levels of ginger extract exhibited a non-significant decrease in shear force values than the control group (Table 2). Data of shear force values are close to that obtained by Abdel-Naeem & Mohamed (2016) they found that camel patties treated with ginger extract alone or combined with papain powder showed the lowest shear force value than control patties. Similar results were found by Abdel-Naeem et al. (2022) who found that camel meat treated with different levels of ginger extract and papain powder showed a significant decrease in shear force values than the control group. In addition, Abdeldaiem & Ali (2014) found that camel meat treated with different levels of ginger extract exhibited significant decrease in shear force value than control group. Generally, the reduction in shear force value in treated sausage with ginger extract may be due to the tenderizing effect of the proteolytic enzyme (Zingibain).

Table 1 Chemical analysis of camel sausage treated with ginger extract

Proximate Composition (%)	Treatments				
	T1	T2	T3	T4	SEM
		Raw sausages			
Moisture	59.24[b]	63.12[a]	61.76[ab]	62.44[a]	0.055
Protein	15.81	15.61	15.64	14.98	0.007
Fat	18.87[a]	13.72[c]	16.25[b]	16.18[b]	0.144
Collagen	1.66[a]	0.86[b]	0.68[c]	0.97[b]	0.026
		Cooked sausages			
Moisture	54.54	56.83	56.59	56.65	0.051
Protein	23.23[a]	22.06[ab]	21.03[c]	21.64[b]	0.065
Fat	13.90[b]	14.02[b]	14.88[a]	15.31[a]	0.109
Collagen	3.24[a]	2.03[c]	3.16[b]	2.89[b]	0.031

[a-c] means within the same row with different superscripts letters are different ($p<0.05$). T1: control, T2: contains 5% Ginger extract, T3: contains 10 % Ginger extract and T4: contains15 % Ginger extract. SEM: standard error of means.

Table 2 Physical properties of camel sausage treated with ginger extract

Physical properties	Treatments				SEM
	T1	T2	T3	T4	
pH value	5.80	5.68	5.66	5.59	0.029
Shear force (Kg/f)	3.06	2.58	2.68	2.59	0.091
Cooking loss (%)	36.53[b]	32.95[c]	39.63[a]	37.27[b]	0.542
Color measurements					
*L**	46.0[a]	44.21[b]	46.39[a]	46.13[a]	0.003
*a**	10.94	10.78	11.09	11.12	0.017
*b**	8.53[b]	8.48[b]	9.00[ab]	9.66[a]	0.714

[a-c] means within the same row with different superscripts letters are different ($p<0.05$). T1: control, T2: contains 5% Ginger extract, T3: contains 10 % Ginger extract and T4: contains15 % Ginger extract. SEM: standard error of means.

Moreover, the solubilized collagen derived from the connective tissues after treatment with ginger extract has excellent water- holding capacity (Badr, 2008). While the higher shear force values of control sausages are due to the high amount of connective tissue in camel meat.

3.2.3. Cooking loss

Significant differences were found in the cooking loss of camel sausages (Table 2). The lowest cooking loss was found in sausage treated with 5% ginger extract, followed by the control group and sausage treated with 15%. The results of cooking loss are consistent with the results of Abdel-Naeem & Mohamed (2016) they found that camel patties treated with ginger extract and papain powder showed higher cooking loss than control patties. Similar results were found by Abdel-Naeem et al. (2022) who found that the cooking loss of camel burgers treated with different levels of ginger extract and papain powder was higher than control group. Contrarily, Abdeldaiem & Ali (2014) indicated that treated camel meat with different levels of ginger extract significantly decreased the cooking loss and increased the cooking yield in the control group. While Moeini et al. (2022) proved that no significant differences in cooking loss between control and camel meat treated with ginger extract and citric acid.

3.2.4. Color measurements

Color measurements of camel sausages are shown in Table 2. No significant differences were found in L* values among sausages treatments and control group except for sausage treated with 5% ginger extract which exhibited the lowest value. On the hand, no significant differences were found in a* values despite sausages treated with higher levels of the ginger extract showing higher a* values. While slight significant differences were found in b* values. Sausages treated with 15% ginger extract had the highest b* value followed by sausage with 10 % ginger extract while, no significant differences were found in sausages of 5% ginger extract and control the group. Data of color measurements are close to that obtained by Abdel-Naeem & Mohamed (2016) they found that treated camel patties with ginger extract and papain powder had a slightly significant effect on L* values, a non-significant effect on a* values, while a significant effect was found in b* values among treated patties. Contrarily, Abdel-Naeem et al. (2022) found that treated camel meat with different levels of ginger extract and papain powder significantly affected a* values and had no significant effect on L* and b* values. On the other hand, Karpinska-Tymoszczyk et al. (2022) demonstrated that treated meatloaf with different levels of ginger extract significantly affected L* values, decreased a* values and had no significant effect on b* values.

3.3. Fat retention, moisture retention and shrinkage measurements (%)

Data of fat retention, moisture retention and shrinkage measurements % are shown in Table 3. Sausage treated with 5% ginger extract had the higher fat retention, followed by sausages with 15 and 10 %, while the control group had the lowest fat retention. Concurrently, sausage with 5% ginger extract had higher moisture retention. No significant differences were found between other sausage treatments. Fat retention significantly increased in camel sausage treated with different levels of ginger extract. These results are inconsistent with the findings of Abdel-Naeem & Mohamed (2016) who stated that camel burger patties treated with ginger extract (7%) resulted in significantly lower fat retention compared to control patties. On the other hand, the results of moisture retention are consistent with Abdel-Naeem & Mohamed (2016) who indicated that camel patties with 7% ginger extract resulted in a non-significant increase in moisture retention.

Table 3 Fat retention, moisture retention and shrinkage measurements of camel sausage treated with ginger extract

Parameters	Treatments				
	T1	T2	T3	T4	SEM
Fat retention (%)	46.69^{c}	68.39^{a}	55.18^{bc}	59.44^{b}	2.250
Moisture retention (%)	34.62^{b}	40.00^{a}	34.19^{b}	35.50^{b}	0.329
Shrinkage (%)	19.11^{a}	12.20^{b}	13.24^{b}	13.35^{b}	0.813
Reduction in length (%)	16.10^{a}	11.56^{b}	12.46^{b}	11.93^{b}	2.315
Reduction in width (%)	26.74^{a}	14.54^{c}	16.84^{c}	20.32^{b}	6.005

$^{a-c}$ means within the same row with different superscripts letters are different ($p<0.05$). T1: control, T2: contains 5% Ginger extract, T3: contains 10 % Ginger extract and T4: contains15 % Ginger extract. SEM: standard error of means.

Shrinkage measurements of camel sausages are shown in Table 3. It can be noticed that sausages treated with different levels of ginger extract had a lower reduction in length, width and shrinkage than control sausage. Treated sausages with different levels of ginger extract significantly improved the reduction in shrinkage measurements. Also, it can be found that the results of shrinkage measurements are concordant with the results of fat, moisture retention and cooking loss. This finding came by the results of Naeem & Mohamed (2016) who postulated that cooking loss reflects the losses of moisture and fat content during cooking, while fat and moisture retentions reflect the amount of fat and moisture remaining in meat after cooking.

3.4. Histological evaluation

The histological examination of camel sausages treated with different levels of ginger extract stained with H&E are shown in Figures (1, 2, 3, and 4) Light micrograph of control (untreated camel sausage) displayed intact muscle fibers (MF) which were closely bound to each other and large amount of intact connective tissue (CT) as showed in (Fig. 1). Treated sausages with 5% ginger extract resulting in moderated broken muscle fibers (MF) and moderate destructed connective tissue (CT) as found in (Fig. 2). Camel sausage treated with 10% ginger extract revealed severe muscle fragmentation (MF) and severe destructive connective tissue (CT) as showed in (Fig.3). However, light micrograph of camel sausage treated with 15% ginger extract exhibited slight breaks across the muscle fibers (MF) and mild degradation in connective tissue (CT) as found in (Fig.4). These microscopic observations are concordant with the scanning electron micrographs of camel burger treated with ginger extract reported by Abdel-Naeem & Mohamed (2016) and the scanning electron micrographs of camel meat treated with ginger extract examined by Abdel-Naeem et al. (2022).

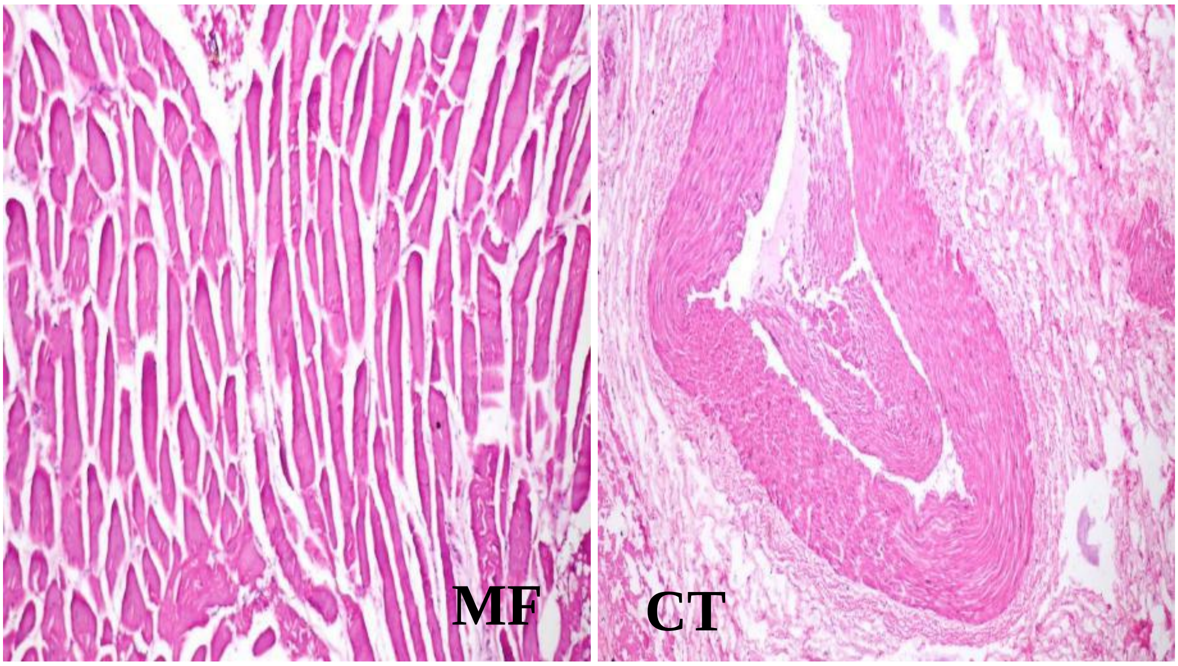

Fig.1. Light micrograph of control camel sausage stained with H&E (×200). MF: muscle fiber; CT: connective tissue.

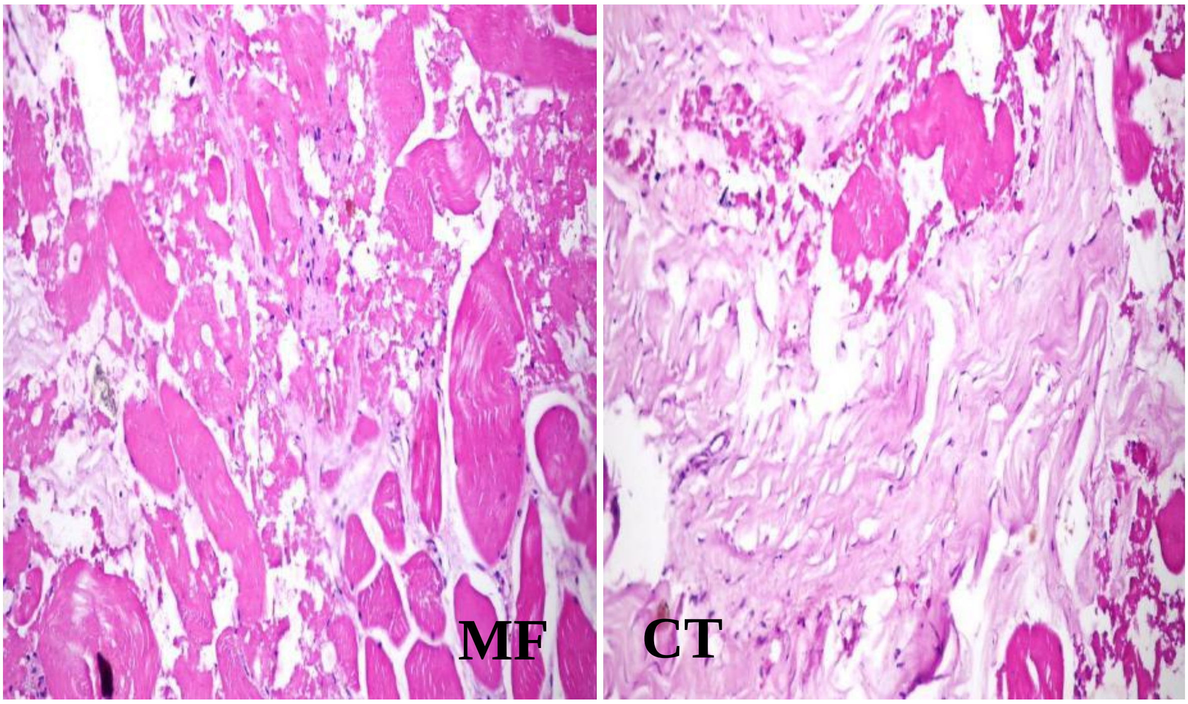

Fig.2. Light micrograph of camel sausage treated with 5% ginger extract stained with H&E (×200). MF: muscle fiber; CT: connective tissue.

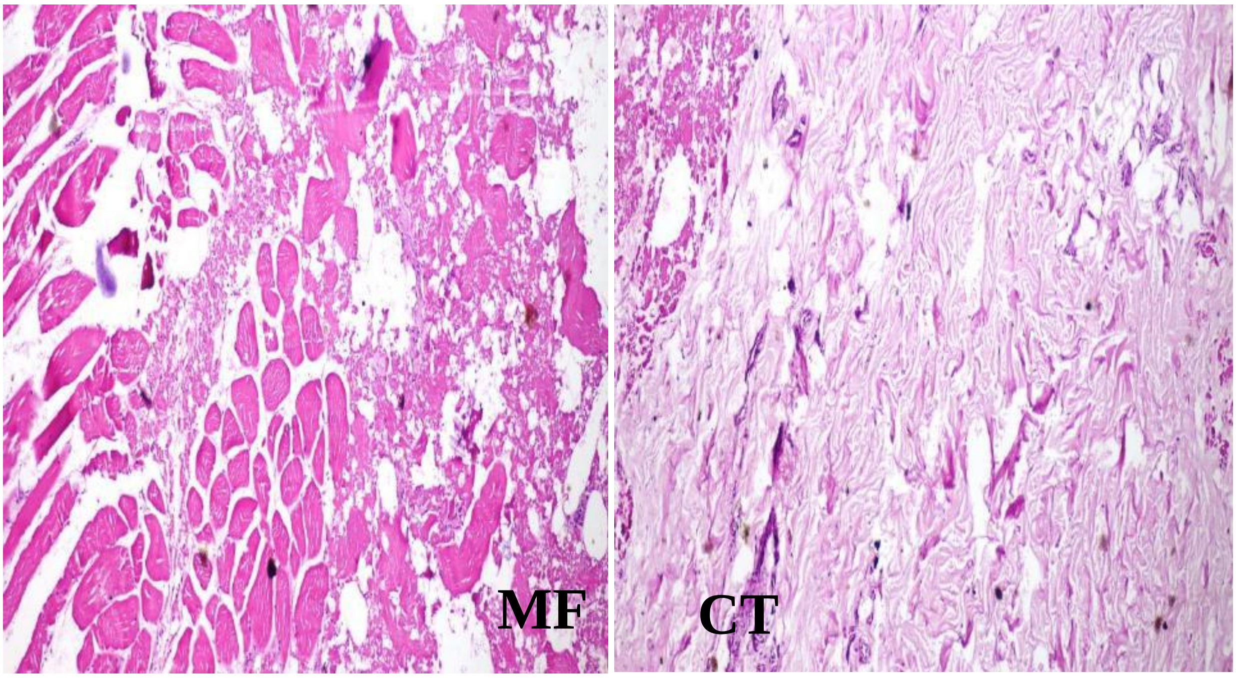

Fig.3. Light micrograph of camel sausage treated with 10% ginger extract stained with H&E (×200). MF: muscle fiber; CT: connective tissue.

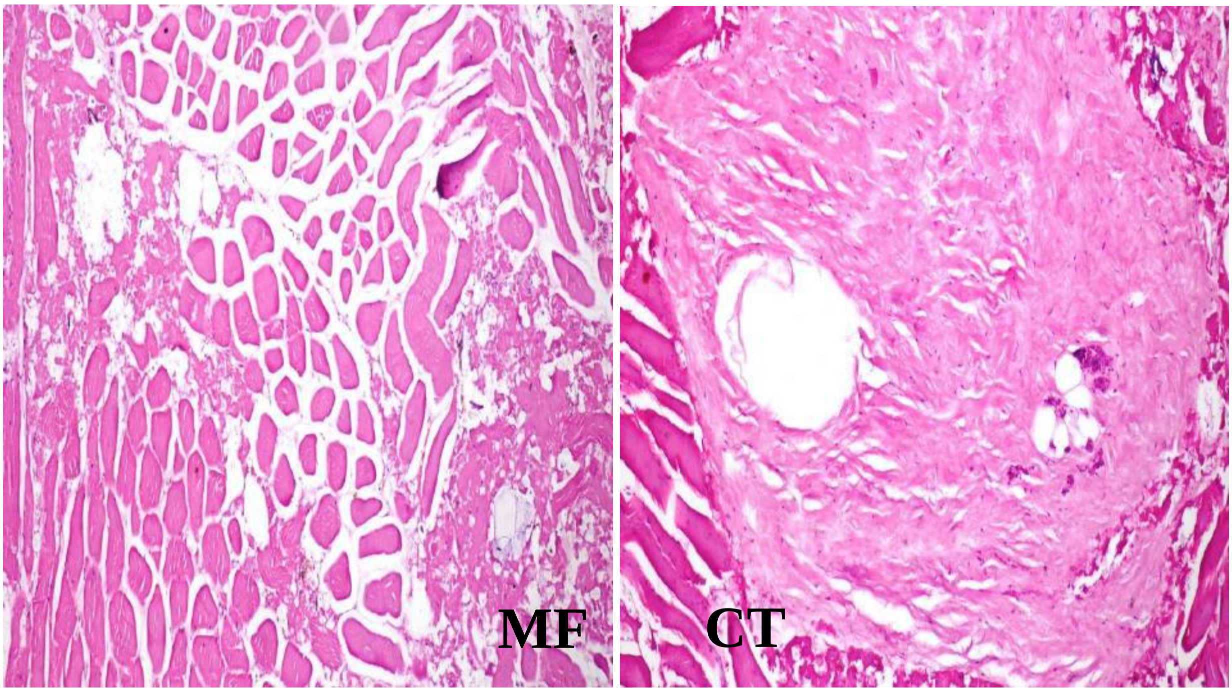

Fig.4. Light micrograph of camel sausage treated with 15% ginger extract stained with H&E (×200). MF: muscle fiber; CT: connective tissue.

3.5. Sensory Evaluation

The sensory attributes of camel sausages treated with different levels of ginger extract are presented in Table 4. No significant differences were found in appearance and juiciness scores between sausages treatments and the control group. Sausage of 10% recorded the highest score for texture, followed by control and sausage of 5% ginger extract. Slight significant differences were found in flavor scores among sausage treatments. The highest score of tenderness was found in the sausage with 10 % ginger extract. However, sausage with 10% ginger extract recorded the highest score for overall acceptability. Camel sausages treated with different levels of ginger extract significantly improved the sensory attributes of sausage. However, the evaluation of sensory attributes for meat and meat products treated with different levels of ginger extract has been reported by different authors (Abdeldaiem & Ali, 2014; Naeem & Mohamed, 2016; Abdel-Naeem et al., 2022; Karpinska-Tymoszczyk et al., 2022; Moeini et al., 2022).

Table 4 Sensory evaluation of camel sausage treated with ginger extract

Sensory attributes	Treatments				SEM
	T1	T2	T3	T4	
Appearance	6.6[a]	6.6[a]	6.8[a]	6.6[a]	0.007
Texture	6.8[b]	6.7[b]	7.0[a]	6.2[c]	0.011
Juiciness	6.7	6.9	6.9	6.6	0.009
Flavor	6.7[ab]	6.7[ab]	7.1[a]	6.3[b]	0.057
Tenderness	6.2[c]	6.8[b]	7.1[a]	6.7[b]	0.025
Overall acceptability	6.8[b]	6.7[b]	7.5[a]	6.3[c]	0.082

[a-c] means within the same row with different superscripts letters are different ($p<0.05$). T1: control, T2: contains 5% Ginger extract, T3: contains 10 % Ginger extract and T4: contains15 % Ginger extract. SEM: standard error of means.

IV. CONCLUSIONS

View on the current study, it could be concluded that the addition of fresh ginger extract to the mature camel meat during the formulation of camel sausage significantly improved the color measurements, decreased the cooking loss, and shrinkage measurements, and increased the fat and moisture retention. Moreover, the addition of ginger extract resulted in significant degradation in muscle fibers and destruction of connective tissue and significantly increased sensory attributes. These effects may encourage meat manufacturers to use mature camel meat as raw material in the processing of meat products that can be accepted by consumers.

ACKNOWLEDGEMENTS

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A Change Analysis of Land Use and Carbon Storage in Maoming Based on the InVEST Model and GIS

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***Abstract*— With the increasing attention paid to ecological and environmental issues, the monitoring and exploration of carbon storage have become increasingly important in ecosystems, attracting numerous attentions from academia and industry. Based on the era background of "double carbon", this study first discussed and sorted out the relevant theories, analyzed the changes and characteristics of various categories in the study area based on land use data, and analyzed the spatial-temporal changes of carbon storages in Maoming City from 1980 to 2020 through transfer matrix and dynamic degree analysis and the InVEST model to explore the impact of land use change on carbon storages. The analysis results show that there is a positive correlation between carbon storage and vegetation coverage, and the transfer of arable land and forest land is the main reason for the decrease in carbon storage. Therefore, it is recommended to pay attention to optimizing land use structures and controlling the expansion of construction land caused by urbanization in order to achieve the goal of protecting the ecological environment.*

Keywords*— Integrate Valuation of Ecosystem Services and Tradeoffs（InVEST）: Land Use/Cover Change (LUCC); Carbon Storage; Transfer Matrix; Dynamic Degree.

I. INTRODUCTION

The improvement of the economic level and scientific and technological progress promote the development of human society while also bringing negative impacts to global climate change and triggering human thinking on sustainable development. Since the industrial revolution, the global climate has worsened day by day. The main reason is that the excessive use of fossil fuels, deforestation, land reclamation, overgrazing, and other irrational land use patterns have led to an increasing number of greenhouse gases in the atmosphere. Therefore, human economic activities exceed the carbon sequestration rate of the system itself, becoming the primary factor affecting the carbon storage of ecosystems (Huang, 2015). The inducing factors that affect carbon storage can be divided into two categories. One is economic factors such as the expansion of infrastructure construction scale, the growth of residents' consumption, and the transformation of land use methods. Another type is policy incentives, which lead to phenomena such as short-lived construction, large-scale demolition and construction, and low-density construction (Huang et al., 2021)。

Land is the foundation of human survival and development, as well as the most important natural resource. With the development of the social economy and the gradual advancement of urbanization, land use has become a topic of great concern. Many studies have shown that land use change is an important reason for the change in ecosystem carbon storage, which leads to a large amount of carbon flowing from the terrestrial ecosystem to the atmospheric ecosystem (Gao and Wang, 2019). In addition, in the process of urbanization, the expansion of urban construction land is caused by land use changes caused by the occupation of forest land, arable land, and grassland, which also makes the urban ecosystem face serious carbon loss problems.

The impact of urban land use change on the ecosystem has been a hot topic in the field of ecology in recent years. Among them, carbon storage is an important link in the ecosystem service function. Vegetation and soil are the two most important carbon pools of the terrestrial ecosystem, and their carbon fixation function plays an important role in alleviating the climate crisis (Bi et al., 2010). Land carbon storage, as an important link in ecosystems, is also a target of concern for many scholars (Poska et al., 2008). For example, Huang (2015) and Zhu et al. (2021) elaborated on the characteristics of land use change, dynamic changes in carbon storage, and the relationship between land use and carbon sequestration, providing references for conducting carbon storage research.

Liu et al. and Ren et al. (2021), based on remote sensing data, obtained the carbon density of Gansu Province by correcting the national carbon density. The modified carbon density was inputted into the InVEST model to estimate the carbon storage of Gansu Province from 1990 to 2015. The impact of land use change on carbon storage was analyzed, indicating that land use change has a significant impact on carbon storage. Luo et al. (2023) coupled the PLUS and InVEST model to study the multi-environmental land use changes and their impact on carbon storage in Xi'an, indicating that the significant expansion of construction land and the encroachment of ecological land and arable land are the main reasons for the loss of carbon storage in the ecosystem. Li and Luo (2023) used the InVEST model to reveal the impact of construction land expansion on regional ecosystem carbon storage in the Karst Plateau region of central Guizhou, China, indicating the impact of urban expansion on carbon storage.

In summary, the InVEST model has become a very popular analytical method for studying carbon storage in ecosystems. In addition, it shows that there are relatively more studies on carbon storage changes targeting countries or provinces, while there is less discussion on carbon storage changes at the city or county level. Based on this, this study will take Maoming City as the research area, explore the relationship between land use change and carbon storage in different periods of time, and provide scientific data references for the optimization of land use structure in Maoming City, as well as response methods to the national "double carbon" goal. Therefore, this study aims to analyze and discuss the land use change and carbon storage of Maoming City from 1980 to 2020 through remote sensing data and the InVEST model, so as to understand the change in carbon emissions caused by land use change.

II. STYDY AREA

Maoming is located in the southwest of Guangdong Province, bordering Yangjiang City in the east, Yunfu City in the northeast, Guangxi in the north and west, and Zhanjiang City in the south. It is one of the most important coastal cities in Guangdong. The terrain is high in the north and low in the south, sloping from northeast to southwest, and located in the south of the Tropic of Cancer. The mountains, hills, platforms, and plains are clearly layered, accounting for 11.2%, 55.8%, 6.6%, and 13.85% of the total land area of the city, respectively. The rivers in this area are developed (Figure 1), accounting for 12.6% of the city's area.

Maoming's petrochemical industry, led by oil refining and ethylene production, occupies an important position in the country. At the beginning of 1959, Maoming's shale mining area gradually developed into an "oil city" with the petrochemical industry as its industry, becoming an important petrochemical production and export base in southern China and an important energy, raw materials, and heavy chemical industry base in Guangdong Province. Rich mineral resources are one of its major characteristics. There are 57 types of minerals identified in the jurisdiction of Maoming, among which the development and processing of mineral resources such as "Nanyu" and kaolin have distinct advantages and characteristics. The total area of the city is 11458 square kilometers, accounting for about 6.4% of the province's total area. As of 2022, the population had reached 6.238 million people. The development of mineral resources has accelerated the urbanization process, and after decades of urban expansion, land use changes have also had significant changes and impacts.

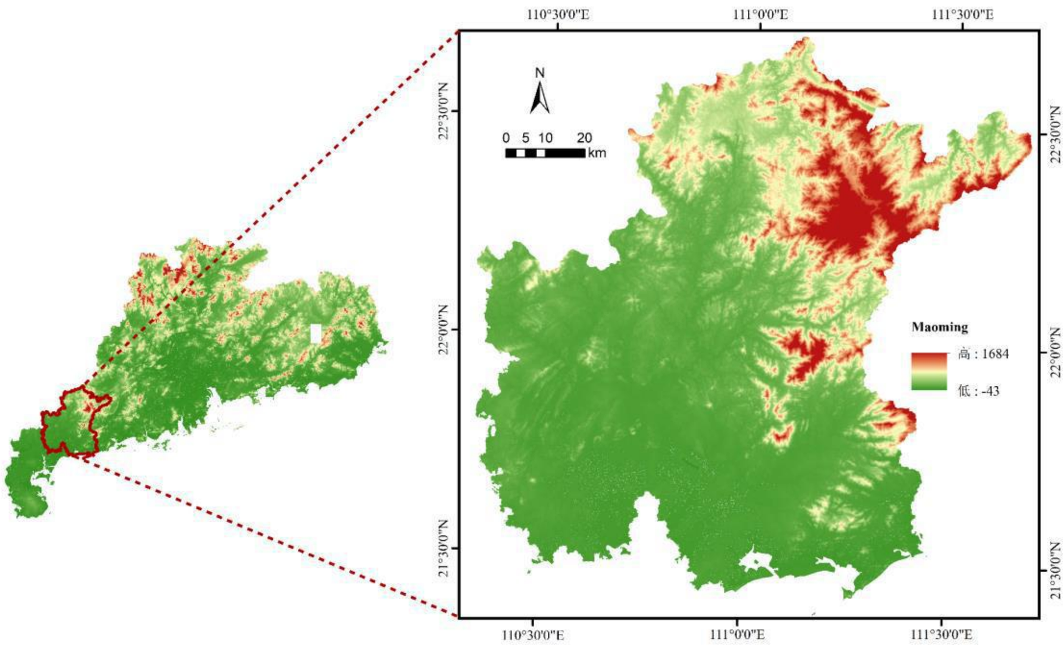

Fig.1 Location and Topographic Map of Maoming City

III. MATERIALS AND METHODS

3.1 Data Sources

The analysis data used in this research are mainly LUCC data from 1980 to 2020, which are from the Institute of Geographic Sciences and Resources, Chinese Academy of Sciences (Table 1).

Table 1 Data Sources and Use Applications

Data type	Data source	Applications
1980-2020 Maoming LUCC data	Institute of Geographic Sciences and Resources, Chinese Academy of Sciences (http://www.resdc.cn)	Produce land use data for five periods

3.2 Methods

This study is based on the land use data of Maoming in 1980, 1990, 2000, 2010, and 2020. The main steps are as follows (Figure 2):

1) Using land use data import ArcGIS and clip to obtain LUCC data for the study area from 1980 to 2020.

2) Reclassify 23 classification data into 6 categories, including arable land, forest land, grassland, water bodies, construction land, and unused land. Finally, process the grid row and column numbers and projection coordinate system in ArcGIS to ensure consistency with other driving factor data.

3) The reclassified grid files are vectorized, fused, and intersected to obtain the land use transfer matrix from 1980 to 2020 and calculate the area change and dynamic degree between different years.

4) Through a literature review, based on previous experience and according to the carbon density correction formula, carbon density data in the Maoming region was obtained.

5) Process the parameters required for the carbon storage and storage module of the InVEST model, and obtain carbon storage and land use grid data. And based on this, obtain a carbon storage map and use ArcGIS to create a spatial distribution map of carbon storage from 1980 to 2020.

6) Finally, according to the analysis data of the land use transfer matrix and the InVEST model, a comprehensive analysis is carried out.

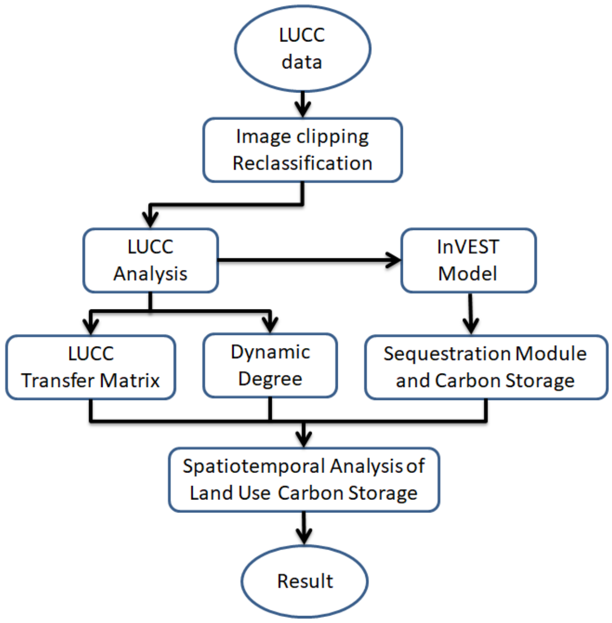

Fig.2 The Schema of the Study

3.3 Land Use Transfer Matrix

The land use transfer matrix (Table 2) is derived from the quantitative description of system state transfer in system analysis (Yu, 2018). Usually, the land use type at time T_1 is represented in rows, and the land use type at time T_2 is shown in a list. P_{ij} represents the percentage of the area converted from land type i to land type j in the total land area between T_1 and T_2. P_{ii} represents the percentage of land types that remain unchanged from T_1 to T_2. P_{jj} represents the percentage of land types that remain unchanged from T_1 to T_2. Pi+ represents the total area percentage of land type i at time T_1. P_{+j} represent the total area percentage of j types of land use at the T_2 time point.

P_{i+}–P_{ii} is the percentage decrease in land type i area between T_1 and T_2. P_{+}j–P_{jj} is the percentage increase in j area during T_1 to T_2 (Liu and Zhu, 2010).

Table 2 Land Use Transfer Matrix Model

T_1	T_2				P_{i+}	Decrease
	A_1	A_2	A	A_n		
A_1	P_{11}	P_{12}	…	P_{1n}	P_{1+}	P_{1+}—P_{11}
A_2	P_{21}	P_{22}	…	P_{2n}	P_{2+}	P_{2+}—P_{22}
⋮	⋮	⋮	⋮	⋮		
A_n	P_{n1}	P_{n2}	…	P_{nn}	P_{n+}	P_{n+}—P_{nn}
P_{+j}	P_{+1}	P_{+2}	…	P_{+}	1	
Newly added	P_{+1}—P_{11}	P_{+2}—P_{22}	…	P_{+n}—P_{nn}		

3.4 Dynamic Degree Model

The regional differences in the rate of land use change can be expressed using a land use dynamic degree model, which represents the changes in land types within a certain time range in the study area, reflecting the magnitude and speed of regional land change. Through the dynamic degree changes in different periods, the characteristics of land use change can be studied, as shown in formula (1).

$$S=\left\{\sum_{ij}^{n}\left(\frac{\Delta S_{i-j}}{S_i}\right)\right\}\times\left(\frac{1}{t}\right)\times 100\% \quad (1)$$

Where formula (1), S_i is the total area of type i land use type at the monitoring start time, $\triangle S_{i\text{-}j}$ is the total area of type i land use type conversion converted to other land use types during the period from the monitoring start to the monitoring end, t is the meaning of time period (a) n, and S is the land use change rate of the study sample area corresponding to time period t. This model can also be used to measure the change rate of a single land use type (Liu et al., 2003). When analyzing the net change and land use conversion of land use types, the area per unit grid is taken as S_i, and the net change conversion area of each type is taken as ΔSi-j, forming the basis for the classification of change maps and conversion type maps.

3.5 InVEST Model

The comprehensive evaluation model of ecosystem services and transactions, referred to as the InVEST model (Integrate Valuation of Ecosystem Services and Tradeoffs, InVEST 3.1), was jointly developed by the World Wide Fund for Nature (WWF), Stanford University, and the Nature Conservancy (TNC) in 2007, aiming to balance the balance between human activities, economic benefits, and the development of natural laws through different land use/cover scenarios and to simulate and evaluate the value of regional ecosystem services to provide support for government decision-making. This paper selects the carbon storage and fixation module of the terrestrial ecosystem to study the change in carbon emissions caused by land use change in Maoming.

3.5.1 Carbon Storage and Fixation Module

The necessary data for this model is land use/cover data, which must be in grid .img or .tif format (unit: meters). The unit of density table for the four major carbon sinks is tons /per hectare, and the table is in CSV format.

The total carbon storage in ecosystems is composed of four basic carbon pools: above-ground biomass, underground biomass, soil carbon pool, and dead organic matter. The above-ground biomass includes tree trunks, branches, etc.; the underground biomass includes the root system of vegetation; the soil carbon pool includes various types of organic carbon in the soil; and dead organic matter includes dead or fallen trees and fallen materials (Hou et al., 2020). By obtaining the carbon density of the four basic carbon pools of different land use/cover types, multiplied by the grid area of each land type, and then converting it to obtain the carbon storage amount per unit area, the expression of carbon storage per unit area is generally expressed in kg/㎡ or t/hm^2. The operating formulas for the four basic carbon sinks are as follows:

$$C_{\text{total}} = C_{\text{above}} + C_{\text{below}} + C_{\text{soil}} + C_{\text{dead}} \quad (2)$$

In the formula (2):C_{total}: Total carbon storage; C_{above}: carbon storage capacity of above ground parts; C_{below}: represents the underground carbon storage capacity; C_{soil}: represents the amount of organic carbon stored in the soil; C_{dead}: represents the storage amount of dead organic matter carbon.

3.5.2 Carbon Storage Data

The InVEST model requires the input of land use data and carbon density values in the study area to form a carbon pool. Data on the general dead organic carbon pool is difficult to obtain (Chuai et al., 2011), so this study refers to the three basic carbon pools. The selection of carbon density data and the accuracy of future land use change simulation plans largely determine the accuracy of the final carbon storage results. Therefore, the determination of carbon density mainly refers to previous studies, and the carbon density data of the study area is obtained by consulting the literature. Because the study area is relatively smaller than the whole country and the literature is lacking, previous studies believe that the difference in carbon density of land types in the same climate zone is small, and the required data can be calculated in areas with similar land use types and climate characteristics (Zhou et al., 2018).

Thus, this study uses the carbon density results of land types in the Guangdong area calculated by Wu et al. (2016) and Lin et al. (2022). The carbon density data of the local land type is corrected by the formula, and the carbon storage density of Maoming is obtained by inversion. Moreover, studies at home and abroad have shown that both biomass carbon density and soil organic carbon density have a significant positive correlation with annual precipitation, while the correlation with annual average temperature is weak. The selection of the formula is mainly based on the universality of the formula and the closeness of the temperature and precipitation in the study area to Guangdong Province. The correction factor calculation formula (Mwambala et al., 2023) is (3), (4), and (5) ：

$$K_{BP} = \frac{C'_{BP}}{C''_{BP}} \qquad K_{BT} = \frac{C'_{BT}}{C''_{BT}} \quad (3)$$

$$K_B = K_{BP} K_{BT} = \frac{C'_{BP}}{C''_{BP}} \times \frac{C'_{BT}}{C''_{BT}} \quad (4)$$

$$K_S = \frac{C'_{SP}}{C''_{SP}} \quad (5)$$

In the formulas (3), (4),and (5), K_{BP}、K_{BT} represent the vegetation carbon density precipitation factor and air temperature correction coefficient; K_B represents the above-ground and underground vegetation carbon density correction coefficient; K_S represents the soil carbon density correction coefficient; and C'、C'' represent the carbon densities of Maoming and Guangdong, respectively, which are calculated by substituting the annual average temperature and annual precipitation into formulas (6), (7), and (8).

$$C_{BP} = 6.798e^{0.0054MAP} \quad (6)$$

$$C_{BT} = 24MAT + 398 \quad (7)$$

$$C_{SP} = 3.3968MAP + 3996.1 \quad (8)$$

(6), (7), and (8), where: MAP represents precipitation; MAT represents temperature; C_{BP}、C_{BT} represent vegetation carbon density obtained from precipitation and temperature, respectively; and C_{SP} represents soil carbon density obtained from precipitation. The comprehensively obtained carbon density values for each land type are shown in Table 3.

Table 3 Carbon Density of Different Land Use Types in Maoming (Unit: t/hm2)

Land use type	Aboveground carbon density	Underground carbon density	Soil carbon density	Dead organic matter carbon density
Arable land	40.37	8.28	11.43	0.00
Forest land	49.34	15.1	20.32	2.82
Grass land	41.18	219.73	10.53	0.24
Water bodies	0.72	0.97	3.19	1.24
Construction land	28.94	5.95	18.94	0.00
unutilized	35.70	7.32	5.62	0.00

IV. ANALYSIS AND RESULTS

4.1 Land Use Change

Through ArcGIS analysis, the land use map of Maoming in five phases from 1980 to 2020 is obtained (Figure 3). According to the classification results, the main types of land use are arable land, forest land, grassland, water bodies, construction land, and unused land. Arable land is concentrated in the southern region; forest land is most widely distributed, concentrated in the north, and also distributed in coastal areas on both sides; construction land is concentrated in each urban area, with Dianbai District and Maonan District being the most prominent. Overall, from 1980 to 2020, the most significant type of land use change was forest land, distributed in the central and southern regions.

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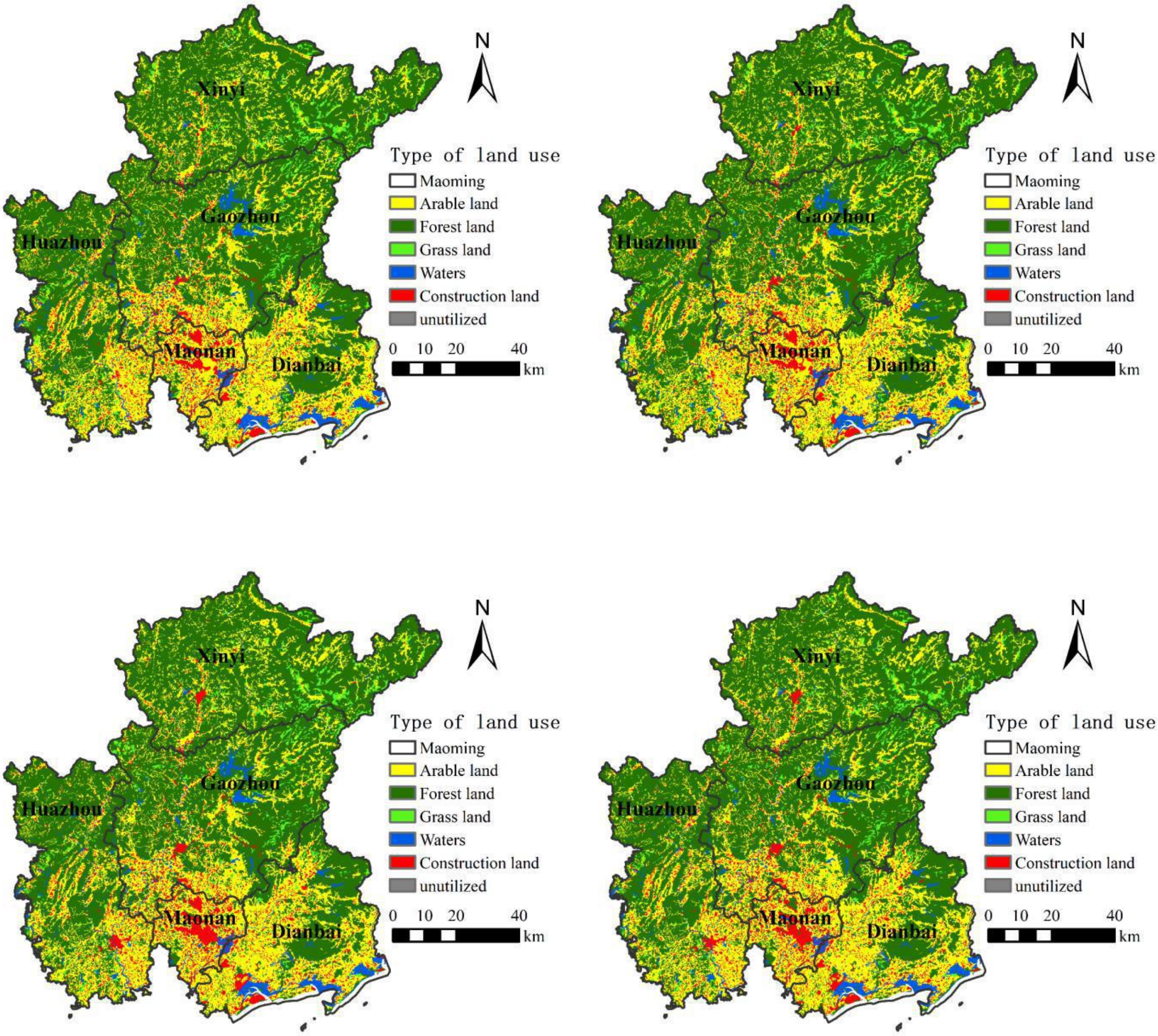


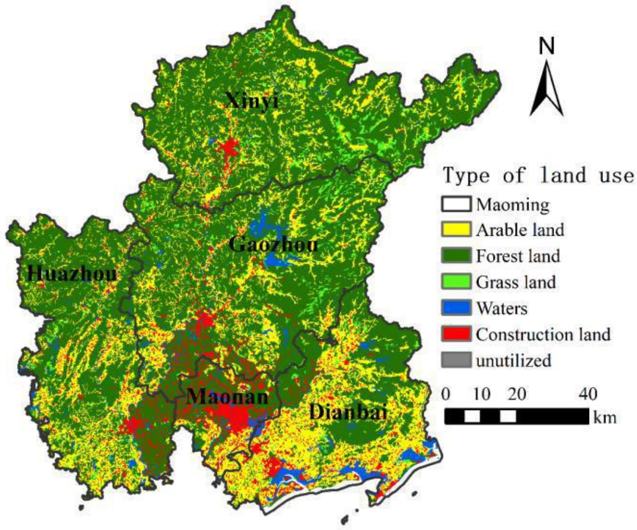


Fig.3 Land Use Map of Maoming from 1980 to 2020

4.1.1 Forest Land is Advantageous Type

Through analysis, the land type area and land use change matrix from 1980 to 2020 are obtained (Table 4 and Table 5). The data shows that forest land is the largest land use type in Maoming, with an area of 7230.9km². The proportion is 58.8–63.6%, which is a dominant land use type. In 1980, the transferred areas of arable land, forest land, grassland, water bodies, construction land, and unused land were 858.5 km², 230.3km²，50.4 km²，43.9 km²，89.3 km² and 6.7 km²；In 2020, the transferred areas of arable land, forest land, grassland, water bodies, construction land, and unused land were 164.0 km², 777.3 km²，43.9 km²，73.6 km²、218.9 km² and 1.5 km².

Table 4 Area (km²）and Rate (%) of Land Types in Maoming from 1980 to 2020

Type	1980		1990		2000		2010		2020	
	Area	Rate	Area	Rate	Area	Rate	Area	Rate	Area	Rate
Arable land	3372.4	29.7%	3360.8	29.6%	3306.9	29.1%	3295.7	29.0%	2677.8	23.6%
Forest land	6683.2	58.8%	6682.9	58.8%	6678.5	58.8%	6703.9	59.0%	7230.9	63.6%
Grass land	352.5	3.1%	353.5	3.1%	349.8	3.1%	339.5	3.0%	346.0	3.0%
Water bodies	320.8	2.8%	322.3	2.8%	324.4	2.9%	332.6	2.9%	351.0	3.1%
Construction land	621.7	5.5%	630.9	5.6%	689.8	6.1%	679.2	6.0%	753.2	6.6%
unutilized	12.1	0.1%	12.1	0.1%	13.0	0.1%	12.8	0.1%	6.9	0.1%

Table 5 Transfer Matrix of Land Use in Maoming from 1980 to 2020 (Unit: km²)

1980/2020	Arable land	Forest land	Grass land	Water bodies	Construction land	Unused	Total
Arable land	--	682.6	4.5	31.2	140.0	0.2	858.5
Forest land	108.6	--	33.5	27.3	59.9	1.1	230.3
Grass land	4.8	40.7	--	2.8	2.1	--	50.4
Water bodies	9.5	19.3	1.9	--	13.1	0.1	43.9
Construction land	40.8	34.4	2.0	12.2	--	0.0	89.3
Unutilized	0.3	0.3	2.0	0.2	3.8	--	6.7
Total	164.0	777.3	43.9	73.6	218.9	1.5	--

4.1.2 Change Condition of Forest Land

The order of changes in land use types from 1980 to 2020 is arable land>forest land>construction land>water bodies>grassland>unused land, with the highest reduction in arable land, with a total reduction of 694.5km². Secondly, the grassland has decreased by 6.5km², reducing unused land by 5.2km². The largest increase in area was in forest land, with an increase of 547.7 km² from 58.8% in 1980 to 63.6% in 2020, followed by construction land, with an increase of 131.5 km². Then there was the water body, with an increase of 30.2 km². The data shows that the expansion degree of forest land has obvious characteristics compared to other land types.

Through analysis, the land change map of Maoming (Figure 4) is obtained. The data shows that the transformation between arable land, forest land, and construction land is the main feature of land use change in Maoming. The total area transferred out accounts for 39.3% of the total area of transferred land. Among them, the transfer of arable land is the main body of land transfer, which is distributed in the south, including Dianbai District and Huazhou City, and also in the north and middle. The distribution of forest land conversion areas is scattered and evenly distributed in the form of small patches. The area of grassland transferred out is distributed in the northeast of Maoming, and the transfer pattern is relatively concentrated. Overall, the land use conversion rate changed significantly from 2010 to 2020, with arable land, grasslands, and water bodies showing a degradation trend, while construction land, unused land, and forest land showed an expansion trend.

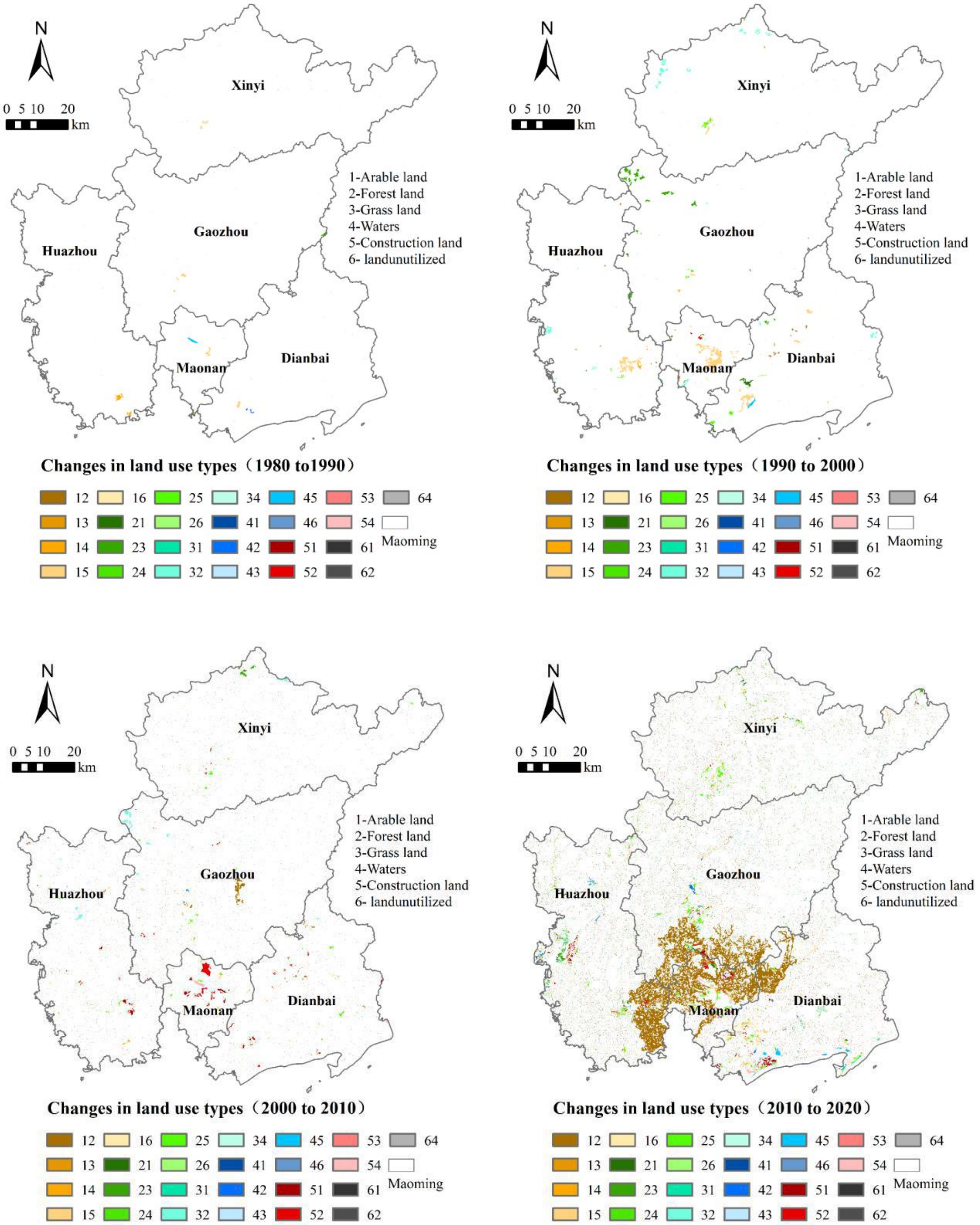


Fig.4 Land Change Map of Maoming

Through analysis, we can get the change in land type area and dynamic degree in Maoming from 1980 to 2020, as shown in Table 6. The land dynamics from 2010 to 2020 were relatively high, at 38.73%; the dynamic degree of land use was the lowest from 1980 to 1990, at 1.99%; the total area of unused land remains basically unchanged, while the total area of construction land and forest land shows an increasing trend. From 1980 to 2020, the highest dynamic land type was unused land, accounting for 55.38%, followed by construction land, arable land, water bodies, forest land, and grassland, with proportions of 23.28%, 21.03%, 9.19%, 8.31%, and 6.18%, respectively.

Among the types of land use, forest land, water bodies, and construction land show an increasing trend, while grassland, arable land, and unused land show a decreasing trend. From 1980 to 2020, the main feature of land use type change in Maoming was the increase of forest land, followed by construction land. From 1980 to 1990, in the early stages of reform and opening up, this stage was a period of continuous economic development. In response to an adaptation to the reform and opening up, humans extensively cultivated wasteland, resulting in a reduction in wasteland area. After 2000, due to rapid socio-economic development, continuous population growth, and the promulgation of government policies, the demand for land by humans continued to increase, leading to the expansion of construction land and a sharp decrease in arable land. With the adverse effects of economic development, such as severe environmental pollution and ecological damage, the government has taken a series of policy measures to promote ecological construction and environmental protection. As a result, from 2000 to 2020, the area of forest and grassland increased, and the speed of urban expansion slowed down. This has also increased the protection of the water environment and promoted the restoration of the ecological environment.

Table 6 Change Area (Km²) and Dynamic Degree (%) of Land Type from 1980 to 2020

Type/Year	1980-1990		1990-2000		2000-2010-		2010-2020	
	Change	Dynamic Degree	Change	Dynamic Degree	Change	Dynamic Degree	Change	Dynamic Degree
Arable land	-11.6	-0.34%	-53.9	-1.60%	-11.2	-0.34%	-617.9	-18.75%
Forest land	-0.3	-0.01%	-4.4	-0.07%	25.4	0.38%	527.0	7.86%
Grass land	1.0	0.28%	-3.7	-1.03%	-10.3	-2.95%	6.5	1.92%
Water bodies	1.4	0.45%	2.2	0.67%	8.2	2.53%	18.4	5.54%
Construction land	9.2	1.49%	58.9	9.34%	-10.7	-1.55%	74.1	10.90%
unutilized	0.0	0.12%	0.9	7.30%	-0.2	-1.75%	-5.9	-46.21%

4.2 Changes in Carbon Storage

The carbon density data of land type in Maoming was obtained by consulting relevant literature and formula correction, and the carbon storage data of 1980–2020 was obtained by importing the carbon storage and storage module of the InVEST model in combination with the data of land use type (Figure 5). The total carbon storage for five years is 92027540.92t, 92032739.8t, 91893990.21t, 91715459.31t, and 93182099.04t, respectively. Overall, carbon storage decreased by 312081.61t from 1980 to 2020, with a decreasing trend from 1990 to 2010 and an increasing trend from 2010 to 2020. This should be related to the increase in forest land mentioned above.

In general, the regional carbon storage changed dramatically from 1990 to 2000. During this period, Maoming's economy grew rapidly, urbanization accelerated, and the demand for land development was also strong. Forest land and arable land were developed and used, resulting in carbon loss. After 2010, the expansion of construction land tends to ease, and land change gradually stabilizes. In response to national environmental protection policies, the restoration of ecological parks is increasing, which presents a favorable situation for the increase of carbon storage.

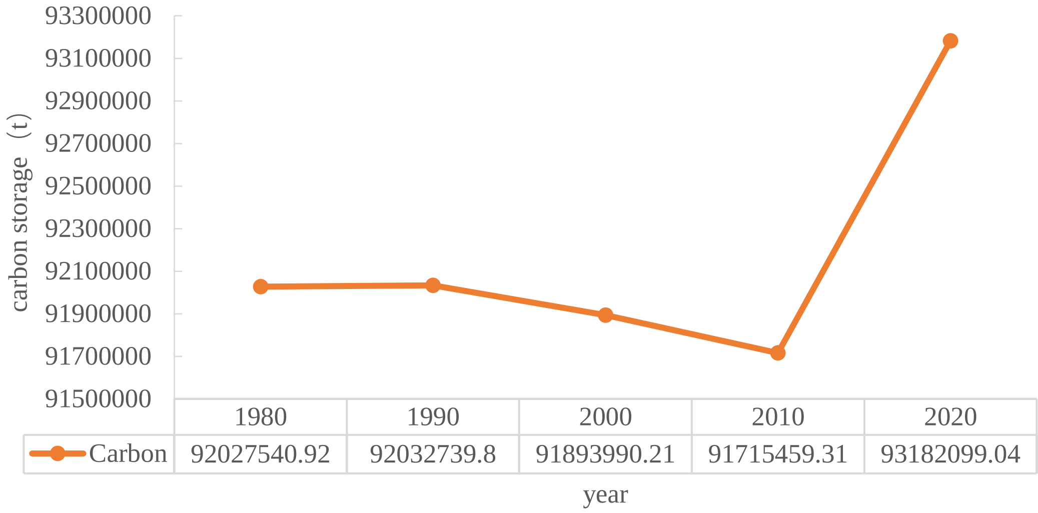
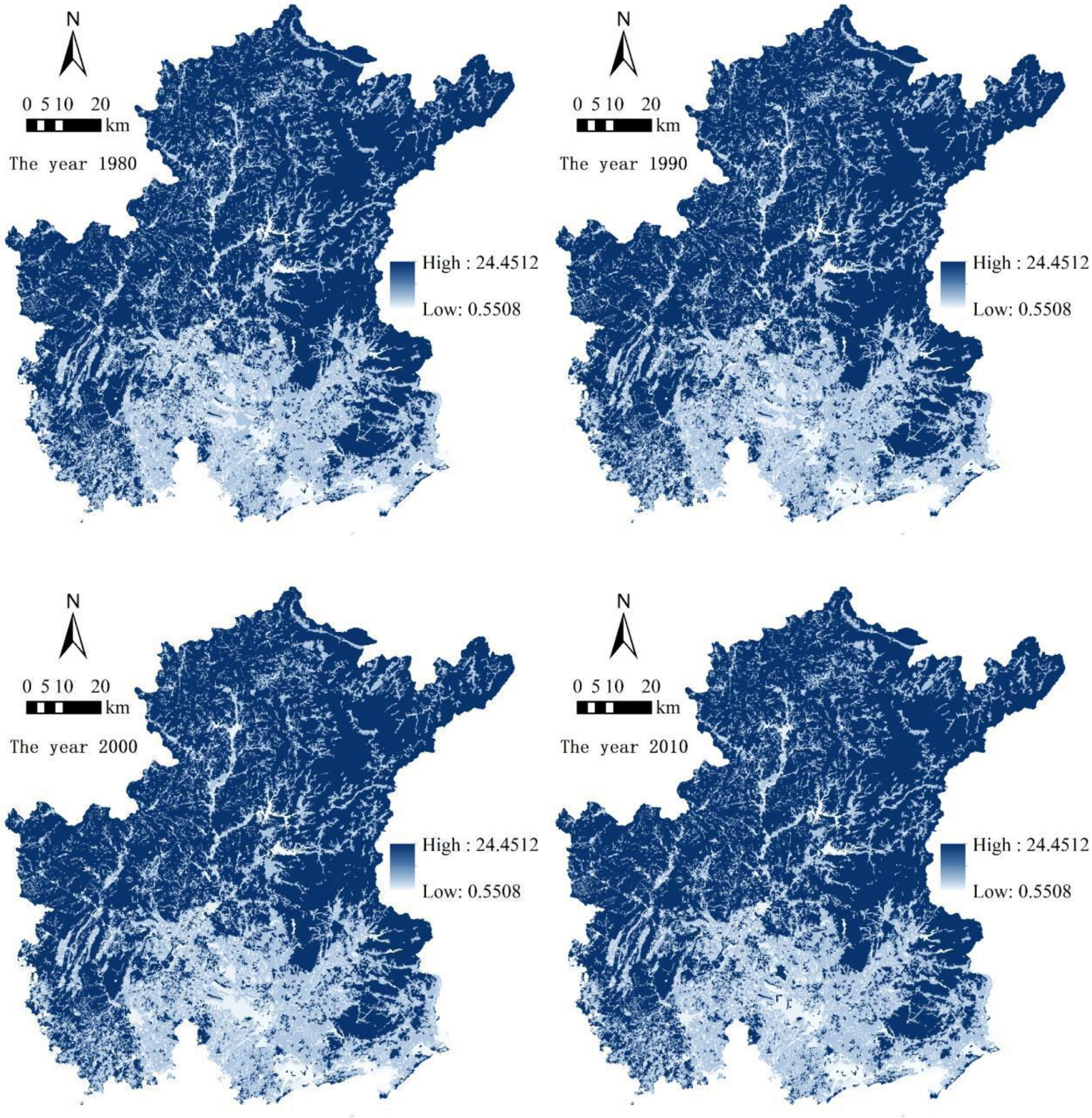


Fig.5 Change of Terrestrial Carbon Storage in Maoming from 1980 to 2020

4.3 Spatial Variation Characteristics of Carbon Storage

After calculation, the distribution of terrestrial carbon storages in Maoming is obtained (Figure 6). The results show that the regions with high carbon storages are distributed in the north, west, and east, namely the north of Huazhou City, Gaozhou City, and Xinyi City. The carbon storages in the south are relatively low and are distributed in Maonan District, Dianbai District, and the south of Huazhou City. This is because the northern region has high vegetation coverage and relatively high altitude, which is not conducive to urban expansion, is conducive to the generation of carbon storages, and is not easy to lose. The northern region has a relatively high altitude, with landscapes such as Tianma Mountain, Shigen Mountain, and Xianren Cave, as well as a high coverage of forest land area. There are also mountain ranges developed in the eastern and western regions. Low carbon storage areas are mainly concentrated in the arable land, water bodies, construction land, and other areas in Maonan District, which are mostly plain areas with flat terrain suitable for human social production activities, relatively low vegetation coverage, and weak carbon sequestration capacity.

From the perspective of spatial changes in carbon storage, the changing regions exhibit a scattered distribution characteristic. From 1980 to 2000, the regions with significantly reduced carbon storage were distributed in the central and western regions of Huazhou, the northwest of Xinyi, the southeast of Dianbai, and the southwest of Maonan District. During this period, the expansion of construction land was intense, and a large amount of arable land and forest land were converted into construction land. After 2010, the urban expansion capacity gradually decreased, the land type remained relatively stable, and the changes in carbon storage also tended to stabilize. There was a significant increase in regional distribution in the central and western regions of Huazhou, the northwest of Gaozhou, and the western regions of Dianbai. According to the data analysis, the distribution pattern of carbon storage in Maoming during the five phases was obtained (Figure 7), in which the arable land showed a downward trend, with the largest decline from 2010 to 2020; the overall growth trend of forest land is showing, with a relatively fast growth rate from 2010 to 2020; and the carbon storage of construction land areas has steadily increased, which should be related to urban greening. In general, the carbon storage of Maoming declined significantly before 2010, but the decline gradually slowed after 2010, and the overall carbon storage change was relatively moderate.



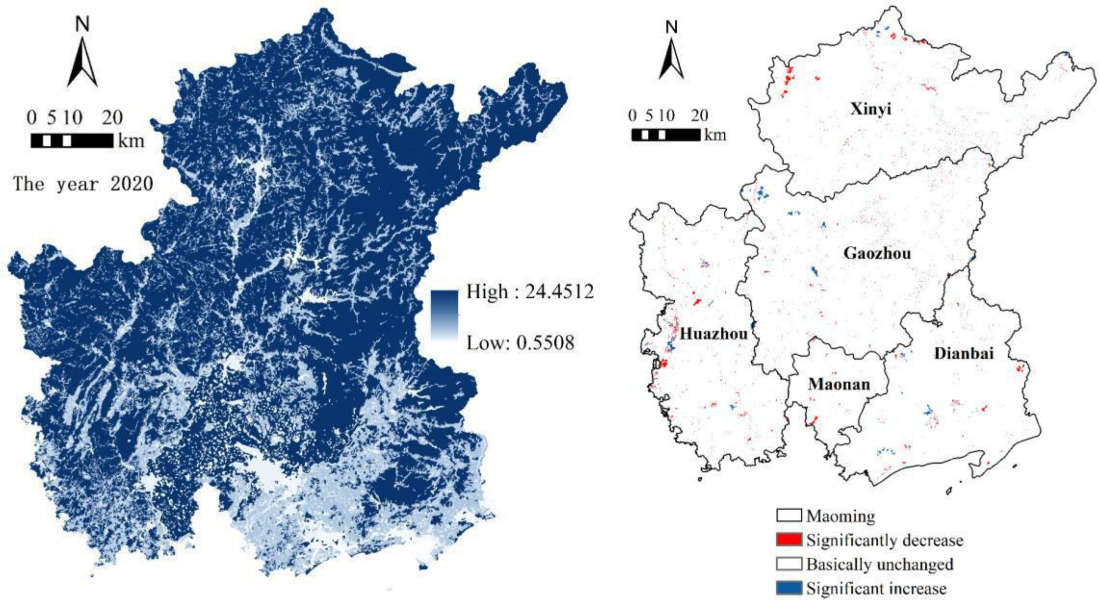
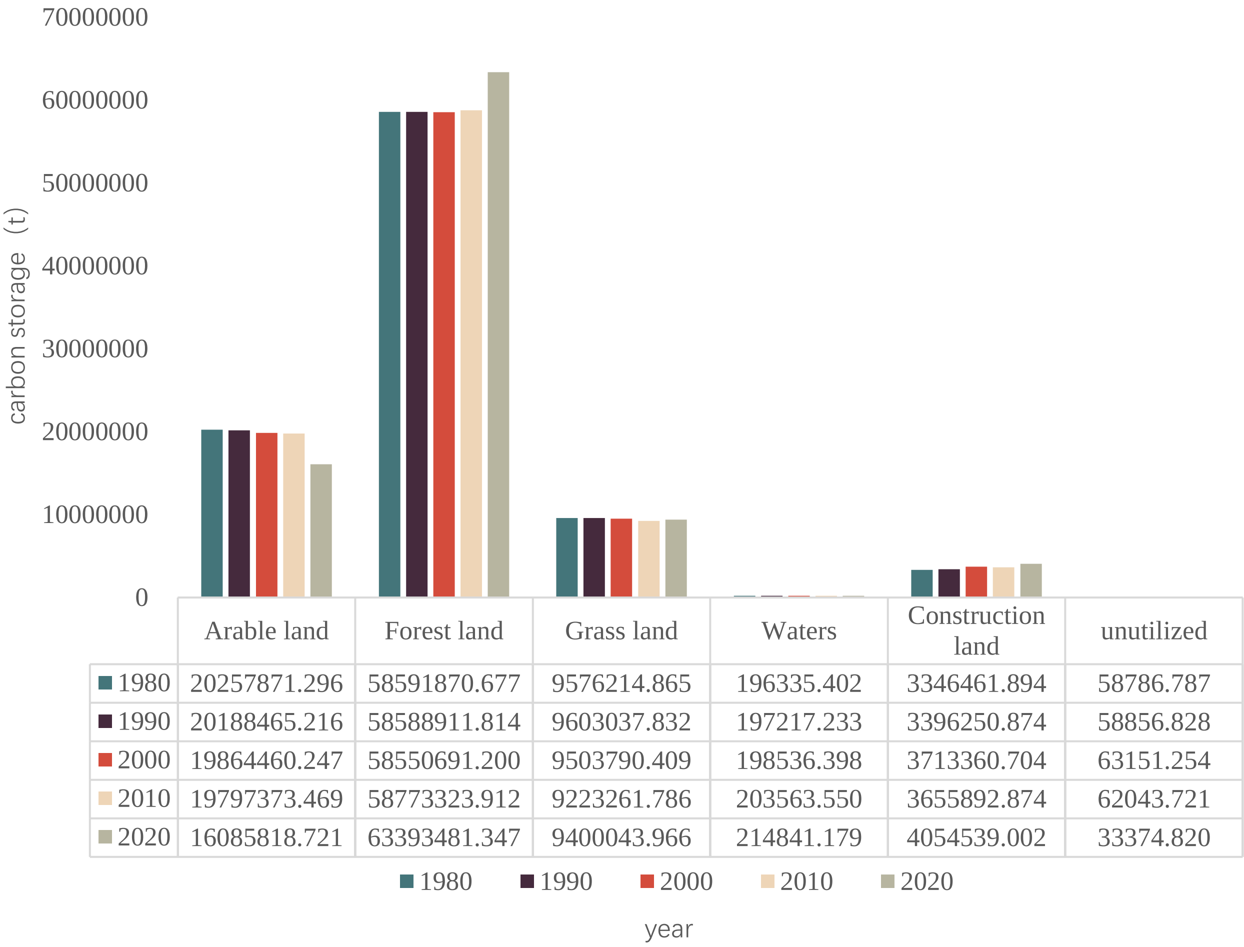


Fig.6 Spatial Change of Terrestrial Carbon Storage in Maoming



	Arable land	Forest land	Grass land	Waters	Construction land	unutilized
1980	20257871.296	58591870.677	9576214.865	196335.402	3346461.894	58786.787
1990	20188465.216	58588911.814	9603037.832	197217.233	3396250.874	58856.828
2000	19864460.247	58550691.200	9503790.409	198536.398	3713360.704	63151.254
2010	19797373.469	58773323.912	9223261.786	203563.550	3655892.874	62043.721
2020	16085818.721	63393481.347	9400043.966	214841.179	4054539.002	33374.820

Fig.7 Change of Carbon Storage in Maoming in Five Periods

V. CONCLUSION

This study analyzes the land use types of Maoming over five periods and uses two models of transfer matrix and dynamic degree of land use change to collate and summarize the data. According to the LUCC data from 1980 to 2020, forest land is the dominant land use type in the area, with the largest changes in the area of arable land and forest land, reaching 694.5 km^2 and 547.7 km^2, followed by construction land. The transformation of these three types of land use change is the most significant. Meanwhile, by analyzing carbon storage data from five periods using the InVEST model, the spatial pattern of carbon storage distribution was obtained, mainly showing the characteristics of high carbon storage in the north and low carbon storage in the south. The conversion between carbon storage and different land use types has a close relationship that is directly proportional to vegetation coverage. The high coverage in the north indicates good carbon sequestration ability.

Overall, the carbon storage in this research area has shown an increasing trend over the past 40 years, from a total of 92027540.92 tons in 1980 to a total of 93182099.04 tons in 2020, with a cumulative value-added of 1154558.12 tons. Among them, arable land and forest land are the most important carbon pools in Maoming. However, with the acceleration of urbanization, a large amount of arable land has been reclaimed, which has become the main reason for carbon loss in this area. With the increase in forest land in 2020, carbon storage capacity has been enhanced, and carbon storages have also increased.

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Climate change impacts on women in Ayodhya and Jaipur emphasize the need for sustainable development in India

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Abstract— *It has been acknowledged that the poor and the impoverished are the most vulnerable to climate change worldwide, and when we consider gender, women are more vulnerable to climate change than males, and as a result, they suffer the most. Because data collectors collect information from household heads, who are primarily men, these women are left out of the data collection process. According to the SDG Report 2022, this is one of the primary difficulties we are now dealing with. For the study, we selected the Indian cities of Jaipur and Ayodhya, and we conducted a qualitative survey of women from underprivileged families, including families Below Poverty Line. The impact of climate change on women's lifestyles, disease transmission, trends natural disasters, food consumption, daily work patterns, changes in traditional knowledge, and why it is important to take action for India's sustainable development are all discussed in this paper. This research will help raise awareness of the regional NGOs and give insight into how to frame policies and initiatives that support women. This research will also shed light on areas with comparable temporal patterns, such as Jaipur and Ayodhya, in other parts of the world.*
Keywords— ***Climate change, Sustainable development goals, Women, Jaipur, Ayodhya, food security***

I. INTRODUCTION

Climate change refers to long-term shifts in temperatures and weather patterns. Climate change is happening, and the repercussions are discernible - glaciers are melting, deserts are becoming hotter and drier, frequency of extreme and violent weather events is increasing, early melting of frozen rivers and lakes (IPCC 2021), more extreme rainfall events (USEPA 2004), more and active wildfires (C2ES 2015) and changing weather and season patterns. Greenhouse gas concentrations are at their highest levels in 2 million years. As a result, the Earth is now about 1.1°C warmer than it was in the late 1800s. The last decade (2011-2020) was the warmest on record (https://www.un.org/en/climatechange/what-is-climate-change accessed on 15 November 22). Turning our greenhouse gas emissions to zero would help halt climate change. Between 3.3 billion and 3.6 billion people more than 40% of the world's population, live in places andsituations highly vulnerable to climate change (IPCC Report 2022- 6th AR). Women are not only first observers but also among the first victims of adverse impacts of climate change (Nelemann et al. 2011, Nwoke and Ibe, 2014). Women have gained special knowledge about the local environment and other natural resources by performing essential activities (e.g., Fetching water, growing food, gathering fuel wood, tending domestic animals, rearing children, and caring for elders) (Dankelman, 2001, Jara 2010). The impact of climate change leading to floods,droughts, etc, results in poor access to medical care and puts this gender at considerable health risk. Urban migration for employment mostly affects women since they face unhealthy situations, lack of sanitation, and unsafe drinking water.

People in all countries that depend most on natural resources for their livelihoods and/or are least equipped to deal with climate change-induced disasters are more vulnerable to the effects of climate change. Since most of the world's poor are women, they frequently face additional risks and burdens from the impacts of climate change (UNFCCC 2021). Most people, even those severely affected by climate change, have no idea what it is or how it affects them. Adverse impacts of climate change threaten agricultural production, fuel wood supply, and water security (Piao et al. 2010; Wheeler and von Braun 2013). Many water-borne infectious diseases are on the rise as a result of water and drinking water scarcity. Climate Change is a growing and persistent driver of inflation. Women comprise over two-thirds of the labour force in emerging nations and over 90% in certain African countries. (UNWomenWatch:www.un.org/womenwatch accessed on 13 November 2022). Due to their disproportionate position in the labor and decision-making processes, women can usually not fully participate in planning, policy creation, and implementation linked to climate change. Women and girls can act as change makers in their communities, empowering them to lead resilient, local, and rights-based climate adaptation solutions. Heat and drought harm food security, water access, sanitation, and air quality, risking maternal and newborn health. (https://www.pathfinder.org accessed on 13 November 22). Women are essential to keep up with SDG goals. If we look at India's SDG 2022 profile, it is ranked 121- with the Climate Change goal in the Green category (SDG achieved), with all CO_2 emissions indicators improving while other categories influenced by climate change are deteriorating.

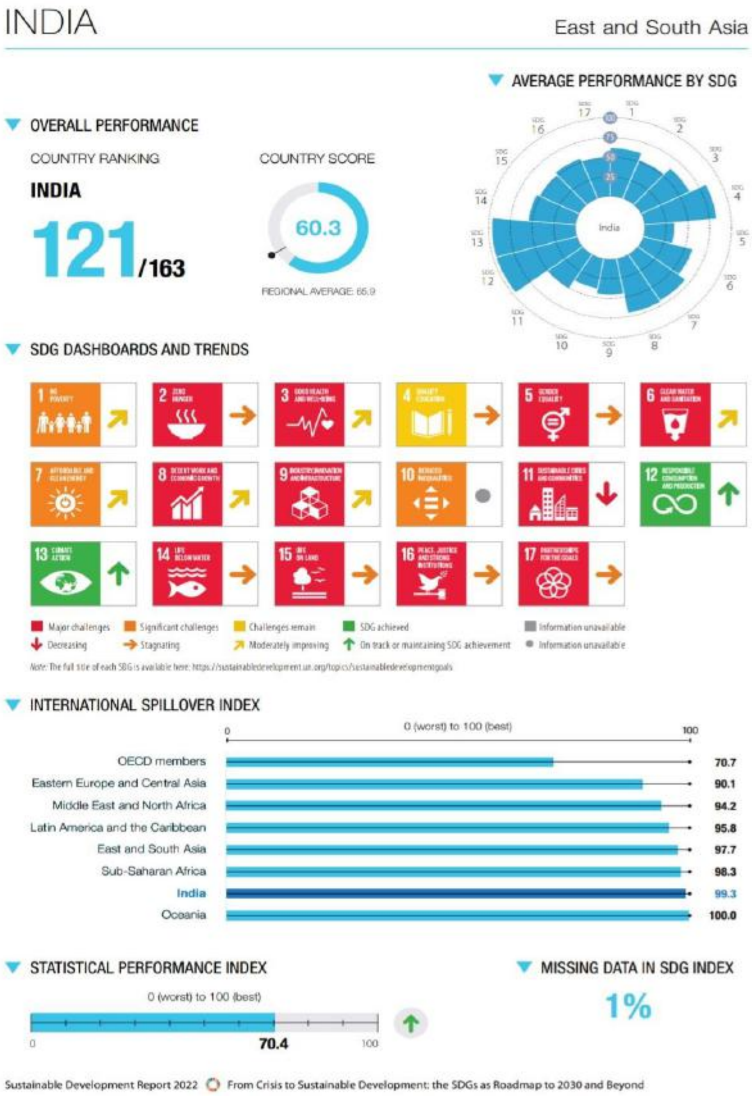

Fig.1 Showing overall performane of India in Sustainable Development Report 2022

Source – Sustainable Development Goals – India Profile According to which SDG 1 - Zero Poverty and SDG 10 - Reduced Inequality are in the Orange (Significant Challenges Remain) category, whereas SDG 2 - Zero Hunger, SDG 3 - Good Health and Wellbeing, SDG 5 - Gender Equality, SDG 6 - Clean Water and Sanitation, SDG 8 - Decent Work and Economic Growth, SDG 10 - Reduced Inequality, SDG 11 – Sustainable cities and communities are classified as Red (major challenges remain). (https://dashboards.sdgindex.org/profiles/india - visited on 31/10/2022),

Impact of climate change in India –

According to studies, India is one of the largest agricultural countries in South Asia. It has a population of over 1.4 billion people and diverse geography, making it one of the world's most vulnerable regions to climate change. The Indian region is also susceptible to extreme weather conditions, such as tropical cyclones, thunderstorms, heat waves, floods, and droughts (Verma 2021). According to a report by the Ministry of Earth Sciences – "Assessment of Climate Change over the Indian Region", it has been stated that between 1901 and 2018, the average temperature in India increased by about 0.7°C. The temperatures of the warmest day and the coldest night of the year have increased by around 0.63°C and 0.4°C over the past 30 years (1986-2015). The tropical Indian Ocean's sea surface temperature increased by 1°C on average between 1951 and 2015, significantly over the 0.7°C global average. From 1951 to 2015, rainfall during the summer monsoon (June to September) over India decreased by about 6%, with substantial drops occurring over the Indo-Gangetic Plains and the Western Ghats.

Over the past few decades, there has been a change toward more frequent dry periods (27% more common over 1981–2011 compared to 1951–1980) and more severe rainy spells during the summer monsoon season. Between 1950 and 2015, the frequency of daily precipitation extremes in central India with rainfall intensities of more than 150 mm per day rose by around 75%. In India, droughts are becoming more frequent due to the decline in seasonal summer monsoon rainfall over the past 6–7 decades. From 1951 to 2016, droughts' frequency and geographic area greatly increased (S Chakraborty et al. 2022). These changes have also enhanced the environmental appropriateness for dengue transmission by 11.5% for Aedes aegypti and 12.0% for Aedes albopictus from 1951-60 to 2012-21, also increasing the length of transmission season (M Romanello et al. 2022) and *Aedes aegypti* being the species found in India the increase of threat against spread of diseases like Dengue and Chikungunya has been increased.

Although climate change knows no bounds, The Intergovernmental Panel on Climate Change (IPCC) highlighted the need for more specific information about climate change on regional and local scales. For a country like India, with diversity in geography and culture, more specific regional data is required to come up with the right solution. For this reason, we chose two states, Rajasthan and Uttar Pradesh, in the Performer category of the Sustainable Development Goals India Index 2020-2021 (https://www.niti.gov.in/reports-sdg - accessed on 1 December 2022). Both states have different climatic circumstances, and we picked a developed city in Rajasthan, Jaipur, and a developing city in Uttar Pradesh, to study the influence of climatic and development factors on the impact of climate change on underprivileged women.

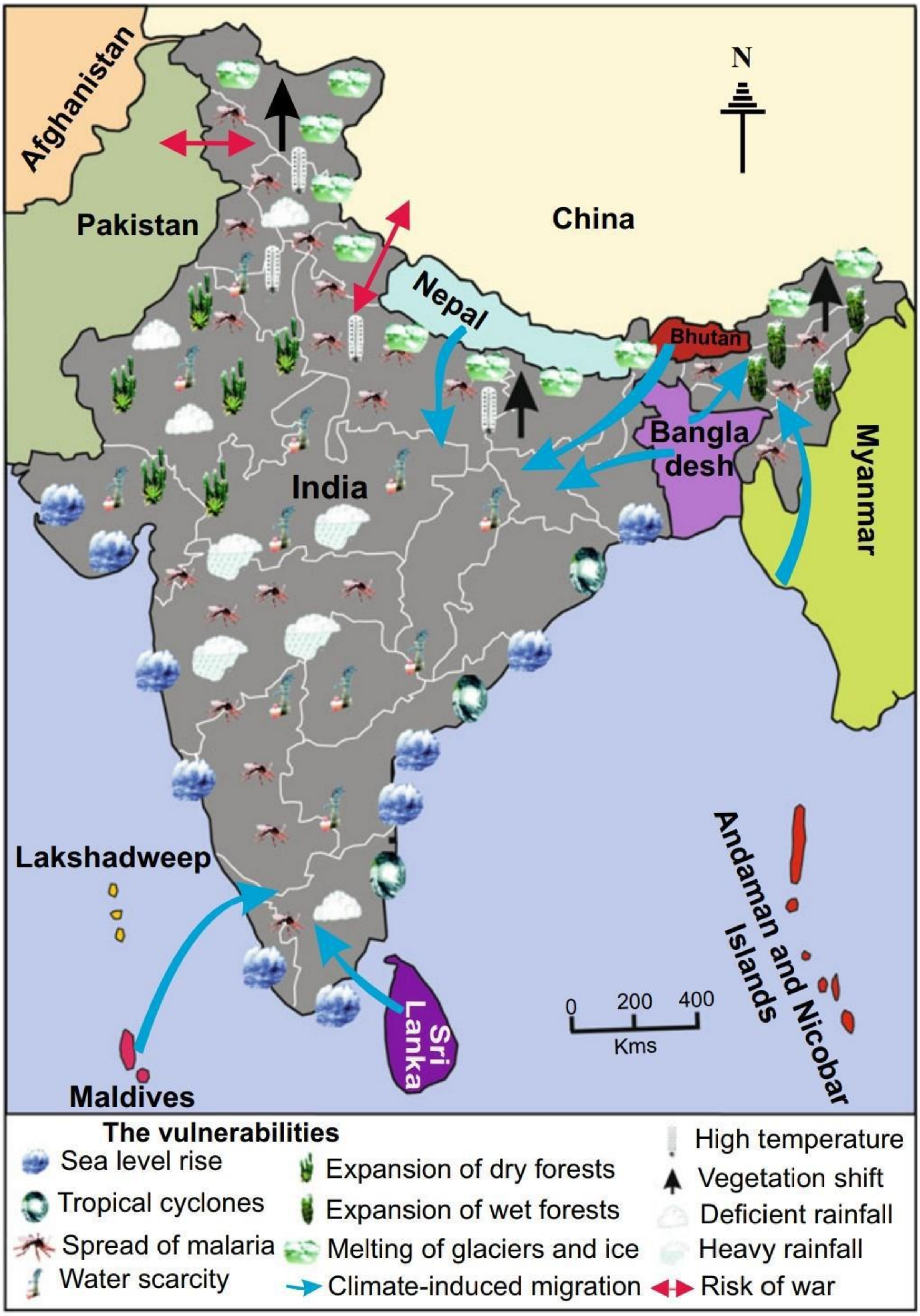

Fig.2 Map of India showing possible impacts of climate change based on multiple sources from 1988-2022

Source- Omkar Verma (2021)

II. METHODOLOGY

We carried out a literature review to understand the impact of climate change in both cities and its effects on the underprivileged women residing there. Following that, we marked the areas based on a preliminary field study. We used a simple random sampling method to select 50 families from both cities for the survey, including Below Poverty Line (BPL) families. Each family's woman was then given a questionnaire survey and interviewed; hence a total of 100 responses were received.

Study Area-

Jhalana, VT Road Mansarover, and Aatish Metro station regions were studied in Jaipur, Rajasthan, which is located on the eastern edge of the Thar desert at an elevation of 0 feet above sea level and has a Subtropical steppe climate (Classification: BSh) (https://tcktcktck.org/india/rajasthan/jaipur- visited on 20/10/2022). In Ayodhya, Madhupur village, Saket colony, and Pura Bazar region were studied. Ayodhya, Uttar Pradesh, is located at 0 feet above sea level and has a Mediterranean, hot summer climate (Classification: Csa) (https://tcktcktck.org/india/uttar-pradesh/ayodhya#t1 - visited on 20/10/2022).

The listed regions in Jaipur are home to many migrants who have migrated to Jaipur and have lived there for over a decade. Women of these migrant families are responsible for household work and also for family income; every woman interviewed in Jaipur worked as a potter, utensil washer, labourer, horseshoe seller, a rag picker, balloon seller, toy seller, and Kalbelia dancer (a traditional dance). Whereas families in Ayodhya's listed regions rely on agriculture, labor, and animal husbandry, women interviewed in these regions were responsible for household work and worked in farms and animal husbandry. All of the respondents are between the ages of 20 and 82.

III. FINDINGS AND DISCUSSION

Respondents' views on climate change

When asked about climate change, no respondent knew what the term meant. However, when asked about changes they had noticed in their local climatic conditions over time—such as changes in rainfall patterns, changes in summer and winter temperatures, the frequency of sandstorms and extreme heat in the summer, the frequency of natural disasters, and the spread of disease—respondents could describe the changes they had noticed.

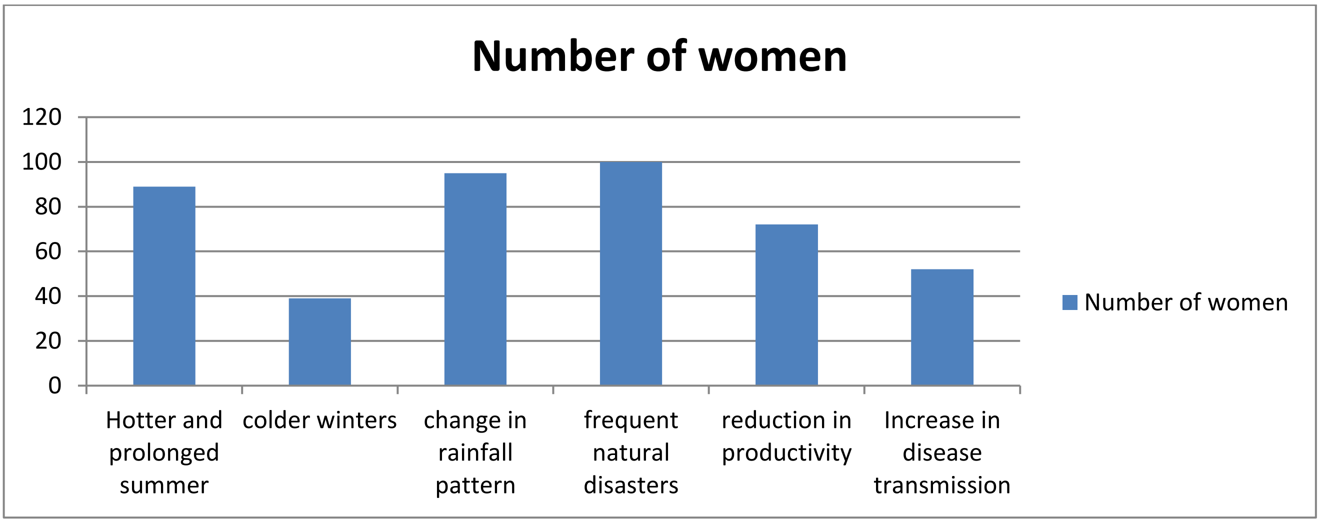

Fig.3 Number of women who observed changes in past 10-20 years

Change in temperature

Out of 100 respondents, 88 reported that summers had become hotter and longer than they had been 10- 15 years ago. After further discussion, this number included 49 respondents from Jaipur and 39 from Ayodhya. Women in Ayodhya explained how they used to have no fans and coolers and had to work outside in fields for longer periods, but with time they gained access to fans and agricultural tools that required fewer human resources in areas, which is why summers were hotter for them before.

Perception of winter temperature showed extreme variations for both cities; out of 100 respondents, only 38 reported cooler winters than 10-15 years ago, while others felt no change; all of these respondents live in Jaipur, whereas women in Ayodhya had a contradictory observation; all 50 respondents reported that winters are warmer than before, and the duration of the winter season has been reduced from before.

Change in Rainfall pattern

95 out of 100 respondents observed changes in rainfall patterns, including all 50 women in Ayodhya, many of whom claimed that due to changes in rainfall patterns, their field's productivity has been decreasing over the years, which is why their family members, particularly men, began working for daily wage labour jobs. These women also mentioned a significant change, which is excessive rain in October, responsible for destroying their rice fields. Whereas 45 respondents from Jaipur stated that the rainy season is arriving later than it did 10 to 12 years ago, causing water shortages. Additionally, when the rain does come, it pours excessively and creates flood-like circumstances.

Frequency of Natural Disasters

All 100 respondents stated that there has been an increase in the frequency of natural disasters. Fifty respondents from Ayodhya claimed that the frequency of floods has significantly increased from 15 to 20 years ago and now occurs yearly during the monsoon season due to excessive rainfall. They also mentioned the water shortage problem they experience each year due to the late monsoon. Women in Jaipur, however, have experienced heat waves, an increase in the frequency of sandstorms, a shortage of water due to drought-like conditions before the monsoon, and water logging following rainfall.

Reduction in Productivity

Out of 100 respondents, 72 stated that they had noticed a decline in productivity, of which 50 women in Ayodhya reported that their agricultural yield had decreased so much due to changes in rainfall patterns that their family members were forced to look for other sources of income. These families had owned agricultural lands for more than 50 to 60 years. In contrast, 23 respondents in Jaipur reported a decline in productivity. Among these respondents were women from families who had left their agricultural lands in other cities decades earlier due to low productivity, insufficient water, and lesser resources. Older women in Jaipur also attributed rising food prices to climate change as it led to less production.

Disease spread

51 of the 100 respondents said they had noticed an increase in disease cases and attributed it to climate change. Thirty-nine women in Ayodhya indicated that they had seen a marked rise in dengue and malaria cases in and around their homes during the rainy season due to the breeding of mosquitoes in standing water. The remaining 11 respondents also reported a rise in typhoid, jaundice, and kidney stone cases in the area, possibly related to contaminated water. Six respondents also claimed that dengue caused the deaths of senior members of their families. Twelve respondents in Jaipur reported a larger number of dengue and malaria infections, as well as a high number of fever cases in their families, but they were unable to identify the sickness that caused the fever; they blamed delayed weather, heat waves, and mosquitoes in stagnant water after rainfall.

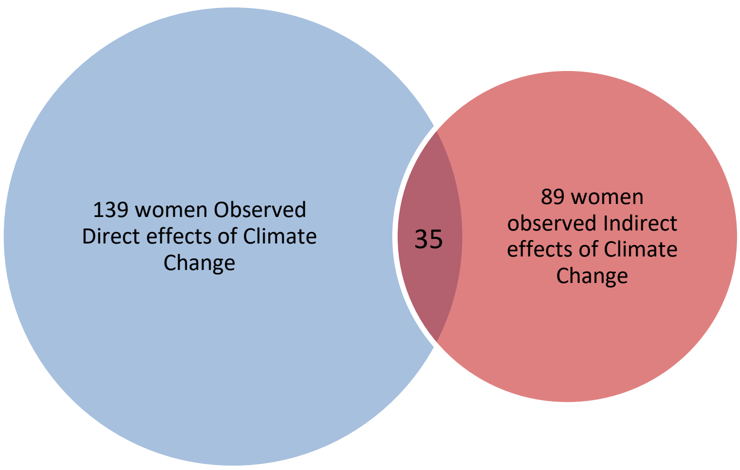

Fig.4 Number of Women that observed Direct, Indirect, and both the impacts of Climate Change in Ayodhya

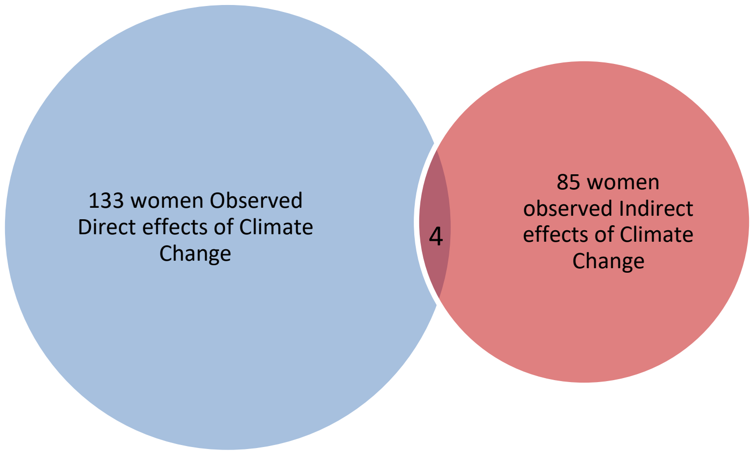

Fig.5 – Number of Women that observed Direct, Indirect, and both the impacts of Climate Change in Jaipur

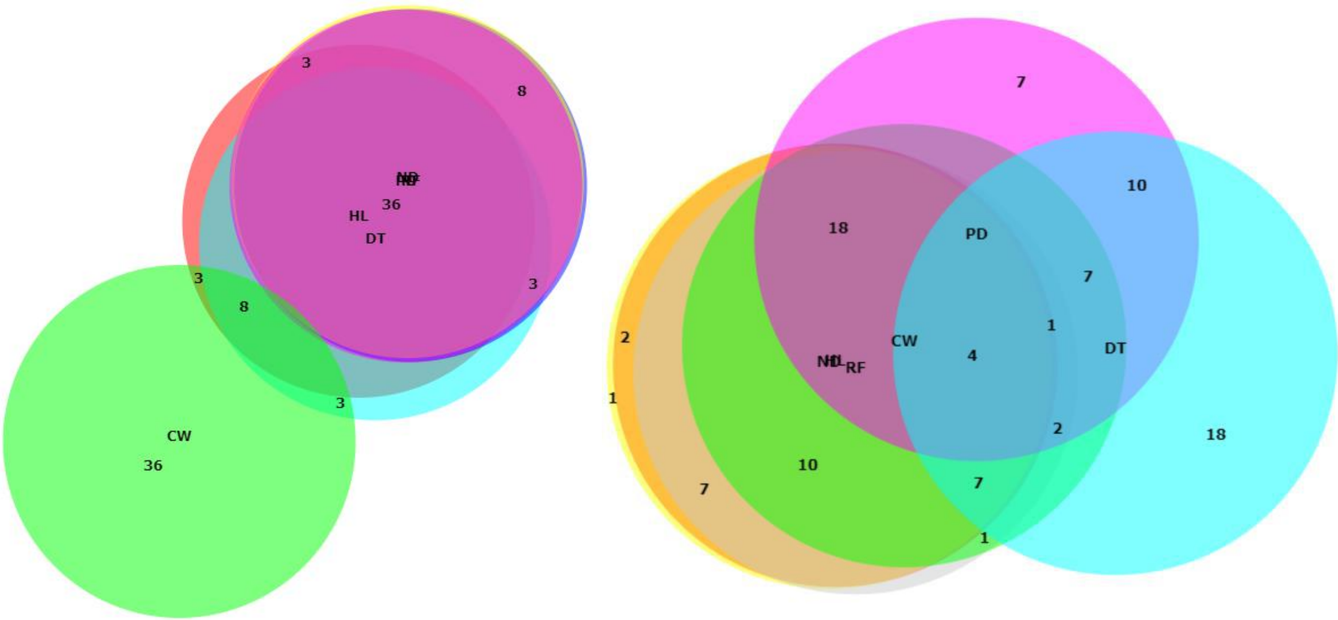

Fig.6 – These two 6-way Venn diagrams show the number of women who witnessed all six effects of climate change: "HL" stands for hotter and longer summers, "CW" stands for colder winters, "RF" stands for change in rainfall pattern, "ND" stands for frequency of Natural Disasters, "PD" stands for reduced productivity, and "DT" stands for disease transmission. In Ayodhya, 34 women could witness all six impacts, but just 4 women could observe the changes in Jaipur.

After the data was collected, it was discovered that women had experienced both the direct consequences of climate change, such as temperature and rainfall, and the indirect effects, such as natural disasters, a decline in productivity, and the spread of disease. Some of these women had even been able to see both. If we look at the numbers for Ayodhya, we can see that women involved in agricultural practices had to suffer from both the effects of climate change, whereas, in Jaipur, where most of the women were migrants, there were very few observers of both. This observation illustrates how migration affects observations.

It was also discovered that most women in Ayodhya could observe all six effects of climate change, whereas only four women in Jaipur could do so. This finding suggests that the women from families relying on agricultural yield for income play a significant role in their observations.

Impact on lifestyle, daily work pattern, and food consumption

Respondents in Ayodhya asserted that the previous 15 to 18 years had seen a significant increase in their hardship and working hours. These women stated that as a result of a drop in agricultural productivity, the men in their households started working in the city to meet their families' food and other needs, and some of them moved to other cities, forcing the women to work longer hours in the fields and spend more time caring for their cattle. Additionally, they asserted that when a family member becomes ill, they must work even harder and travel great distances to receive medical care. Particularly the women in the Madhupur village region complain about this. Furthermore, they mentioned that most of the vegetables and rice they consume come from their land; however, because of the flood, their crops were destroyed, necessitating even more labor for the subsequent harvest. They eat less to reduce consumption due to lower productivity and higher food product prices, and women in the family make the most sacrifices and consume less food than men. They added that they believed new agricultural techniques, such as adding fertilizers, had diminished food products' nutritional value and flavor. These women also claimed that because of housework and working outside, they are the ones who get up first to prepare food for the men and children in the family, and they go to bed last after completing house chores every day, leaving them with little or no time for self-care.

The same problem affects women in Jaipur because they put in the most effort and take care of household tasks before going to work to support their families. Many of these respondents face the threat of migration because they live in temporary tents damaged during sandstorms and are occasionally destroyed by the government, forcing them to work even harder. They also claim that in the last 10-15 years, they have begun to experience water logging due to excessive rain, and they have had to travel further to get water from distant government water facilities than before because rainfall is now delayed, causing water shortages in their area. These women also stated that climate change-induced inflation made it difficult to provide food for their children, which made them fearful for their children. After discussing all the changes they had seen, we asked if they thought they were caused by climate change. Out of 100 respondents, 61 blamed climate change, 21 were unsure, and the remaining 18 denied that climate change was to blame instead, they blamed factors such as governance and lack of opportunities.

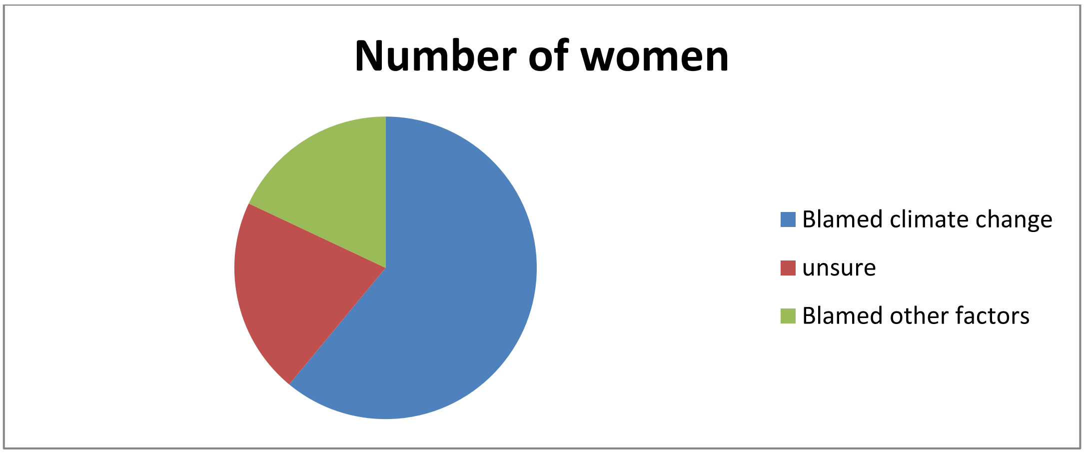

Fig.7- Number of women who blamed changes on 2) Climate change b) other factors, and c) unsure about it

Changes in traditional activities

Observed respondents mention various activities that have declined in the last 10 to 15 years, includingcow dung on the walls of their homes to help cool down during the summer, which no longer works. They also mentioned reduced use of thatch sheds due to increased fire cases during the summer and increased damage from excessive rainfall. They also stated that they can no longer use traditional "Chulhas" during the scorching summer season. Practices such as using wet jute bags, handmade hand fans, pots to store water, and burning dung cakes to eliminate mosquitoes have also declined because they believe they are no longer efficient. They also stated that they rely more on government water supplies because traditional hand pumps do not provide water when the monsoons are delayed. Women in Kalbelia (a traditional dance in Rajasthan) said they don’t want to pass this dance form to their children because it never helped them to escape poverty, and they see no future in the profession. Out of 100 respondents, 53 blamed climate change, 6 were unsure, and 41 blamed factors such as brick house construction, fewer trees, technology, and people having lower tolerance power than before.

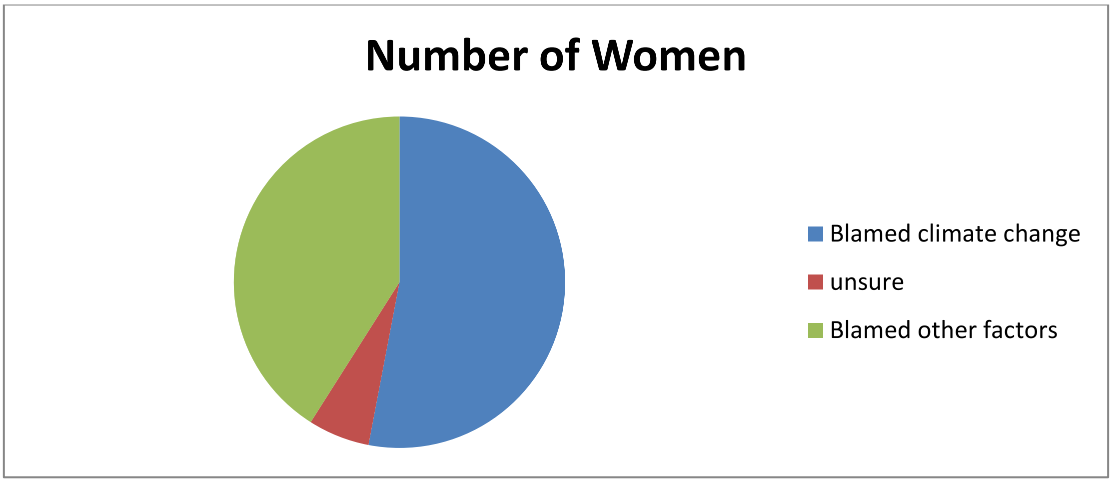

Fig.8 - Number of women who blamed the changes on a) climate change b) other factors, and c) are unsure of it

Gender and data collection

During the discussion, these women also mentioned that they approach the men first if someone comes to the house for a survey or from an NGO. It was also stated that if the data collector or NGO worker is a man, the men in the family do not include women in the discussion. Women in Jaipur stated that they were approached by NGOs that provide them with sanitary products and that they do receive medical benefits from the government, but they said that they want opportunities for themselves. Women in Ayodhya, on the other hand, claim that they do not receive any government support because they are illiterate and unaware of their rights, and no one approaches them to assist them.

IV. CONCLUSION

No respondents in either city knew what the term "climate change" meant, even though it has been established in reports and papers that underprivileged women are vulnerable to it. However, they could feel the changes impacting their lives directly and indirectly. The data revealed that the impact of climate change is heterogeneous based on geography, but it also revealed similarities, such as in the frequency of natural disasters; 100% of respondents felt an increase in natural disasters due to climate change in the past 10-20 years. It was also revealed that these women face gender biases in data collection which is very concerning; even SDG 2022 report mentioned the concern. To progress, we must raise awareness about climate change and how to address it. We require a stronger framework for implementing gender-sensitive climate policies, and women with the majority of information on mitigation and adaptation should have an equal voice in policymaking at the community level (Gupta 2015). Under the environmental policy, these women should be given opportunities such as tree planters and caretakers. If they work on agricultural farms, they should be given advanced technical tools to protect their yield from conditions like waterlogging and need agricultural plans to avoid losses, if not individually, then on a community level. There is also a need to monitor groundwater quality in these poor areas where disease frequency has increased significantly, and awareness about diseases such as dengue and malaria should be spread throughout these regions so that people can take precautionary and responsive actions. It was also discovered that the majority of these families, approximately 63%, owned at least one Smartphone and had internet access, and women in the Kalbelia profession also owned a Smartphone and had internet access. Keeping this in mind, we must encourage greenfluencers to create short videos that can raise awareness about climate and agricultural solutions in various languages. We need to create more climate change-related online programs in local languages, similar to how The University of Edinburgh offers online courses in Bengali. Agricultural solutions that can be made at home, such as Mahadev Gomare's natural pesticide and fertilizer developed in collaboration with Art of Living, should be shared and promoted via the Internet. Climate and agricultural experts should collaborate with companies like YouTube and Instagram to create more content that raises awareness and offers solutions.

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Market Dynamics and Seasonal Pricing of Major Vegetables in Kathmandu Valley

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Abstract— *The off-season vegetables are regarded as important agricultural commodities in Nepal, offering significant commercial potential. These vegetables have been identified as valuable value chains that can improve the livelihoods of small-scale farmers through advancements in production and marketing techniques. This study examines the price flexibility and seasonality patterns of major vegetables in Kathmandu Valley, Nepal, with the aim of providing policy recommendations to address the inelastic demand and reduce import dependency. The analysis reveals mixed elasticity in the demand for tomatoes, with inelasticity from November to March and higher elasticity from April to June. Potatoes exhibit predominantly inelastic demand, while onions demonstrate mixed elasticity with inelasticity from July to October and elasticity from November to April. Additionally, cauliflower and cucumber show high inelasticity during the harvesting season and comparatively elastic demand during off-seasons and pre-harvesting periods. The study also identifies high seasonality in the prices of cauliflower and cucumber, moderate seasonality in onions, and low seasonality in potatoes and tomatoes. Considering the high import share of vegetables in Kathmandu Valley, recommendations are provided to reduce import dependency and promote domestic production. These include supporting local farmers through incentives, access to quality inputs, and agricultural training programs. Improving post-harvest infrastructure, such as storage facilities and transportation networks, is crucial to minimize spoilage and optimize the supply chain. Enhancing market efficiency through streamlined supply chains and transparent pricing mechanisms can benefit both farmers and consumers. Promoting value addition in vegetables, investing in research and development for improved varieties, and fostering collaboration and networking among stakeholders are suggested to enhance productivity, competitiveness, and market expansion. While these recommendations focus on increasing domestic production and market efficiency, further analysis of import dynamics and trade policies is necessary to effectively reduce imports and ensure a balanced market supply.*

***Keywords*— Major Vegetables, Price Flexibility, Seasonal Variations, Kathmandu Valley, Econometric Analysis**

I. INTRODUCTION

Agriculture has historically played a crucial role in the economic landscape of Nepal, contributing approximately 26.50 percent to the country's Gross Domestic Product (GDP) [3]. Specifically, within the agricultural sector, horticulture accounts for 16.75% of the GDP, with vegetables contributing 9.71% and fruits and spices contributing 7.04% [8]. The agricultural practices in Nepal heavily rely on rainfall, with around 67% of cultivation depending on precipitation [10].

Nepal, renowned for its diverse climate and ecological variations, possesses a distinct advantage in cultivating both seasonal and off-seasonal vegetables. As a result, vegetables have become the third most prioritized sub-sector within the agricultural industry, as stated by the Agriculture Development Strategy (ADS). Off-season vegetables such as cabbage, cauliflower, cucumber, tomato, onion, and chili, which are considered commercially significant agricultural commodities in Nepal, have been recognized as highly potential value chains. These value chains have the capacity to enhance the incomes of smallholder farmers by improving production and marketing practices. Consequently, the vegetable sub-sector offers substantial opportunities for commercialization. Compared to cereal crops, vegetables have higher rates of commercialization and a favorable cost-benefit ratio. This sector plays a crucial role in shaping the economic conditions for farmers as it allows for cash generation even from small plots of land within a short time frame. Vegetable cultivation is particularly beneficial for farmers as it supports their livelihoods through food provision, income generation, and employment opportunities. Due to their status as preferred cash crops, vegetables hold significant value in enhancing farmers' overall well-being [4].

Vegetables play an essential role in maintaining a balanced diet as they contribute a significant portion of essential vitamins, proteins, and micronutrients [9]. Although there has been an increase in vegetable consumption among the Nepalese population in recent years, rice remains the primary staple food in their daily diets [1]. According to nutritionists and dieticians, the average per capita daily requirement of vegetables in Nepal is estimated to be 300 grams [12]. However, the actual intake falls significantly below this standard recommendation, with a deficit of 60 percent compared to the quantity of vegetables produced [5].

Owing to factors such as population growth, economic transformations, increased purchasing power from income growth and remittances, the demand for vegetables in Nepal is experiencing rapid surge. However, the current level of production fails to meet this escalating demand [4]. Despite the considerable potential for vegetable production in the country, numerous challenges hinder the growth of vegetable farms. These challenges include the untimely availability of quality inputs, inadequate post-harvest facilities, and the diversion of agricultural loans towards non-productive sectors, resulting in slower progress in increasing vegetable yields [11].

In the agricultural sector, the price of a crop is not primarily determined by its demand, but rather by the elasticity of its supply. The demand for crops tends to remain inelastic, while the supply exhibits high elasticity. As a result, fluctuations in the supply of a crop contribute to variability in its price. The analysis of price flexibility indicates a positive relationship between price and production for gram and mung, which may be attributed to the fact that these crops are major pulses in their respective seasons and experience high demand [2]. Thus, Price flexibility of demand is an important concept in economics as it helps businesses and policymakers understand the dynamics of consumer behavior and market responses to price changes and the seasonality study aid further in seasonal analysis of demand patterns [7].

OBJECTIVES

a) To estimate the price flexibility of major vegetables in Kathmandu Valley.
b) To determine the simple average approach seasonality patterns of major vegetables.
c) To suggest some policy measures based on the results of the study.

II. METHODOLOGY

The true purpose of this study was to assess the existing price elasticity (also, price flexibility) and seasonal alterations in the prices of major vegetables in the selected study area. In order to meet those objectives, planned strategies were implemented to study the site, identify the major vegetables in terms of trade volumes, and type and number of respondents to acquire meaningful data. Consequently, various tools, and techniques in selection of sample, data collection, and analysis and interpretation of data were adopted to attain the targeted goal.

SELECTION OF STUDY AREA

The Kathmandu Valley (KV), comprising of three districts namely, Kathmandu (the capital city of Nepal), Lalitpur and Bhaktapur is the major commercial hub of the nation since time immemorial. The KV, with a total size of 569.80 sq. kms., continued to be significant both politically and economically for hundreds of years. As a matter of fact, the first structured vegetable wholesale market, Kalimati Fruits and Vegetable Market, of the nation was introduced in Kathmandu and continues to be fully operational till date. Moreover, the KV houses the second predominant market, the Balkhu Vegetable Market at its center. Surya Binayak Green Agriculture Wholesale Market, covering 4.4 acres (35 ropani) of land has recently been opened and is the country's largest vegetable market till date. Several other markets namely, Bouddha Modern Vegetable Pvt. Ltd., Icchumati Vegetable Market, Chabahil Vegetable and Fruits Agriculture Market, Gwarko Vegetable and Fruits Market, Sangrila Agro Market, etc. are also situated in the KV, which makes it favorable spot for unbiased data acquisition.

RESEARCH DESIGN, SAMPLING & DATA COLLECTION

The research design for this study was cross-sectional, which allowed for the collection of data from multiple sources at a single point in time. Since the production and marketing of vegetables were a significant economic sector, a large number of people worked in this industry. In the KV, farmers, collectors, wholesalers, and merchants were the primary players in the production and marketing of vegetables. There was a predetermined number of respondents from each link who were chosen to be representative of the entire population. The sample was made up of the chosen respondents, and the sampling technique was the process used to choose the sample. The sampling frame was made up of the commercial vegetable growers involved in vegetable production and collection, wholesalers, and retailers involved in marketing in the KV. To choose the samples from among these, a random stratified sampling procedure was used. To gather the data, a survey of at least 50 commercial growers in the KV and a few nearby areas was conducted. Similarly, to investigate the flow of vegetables in the market, interviews were also conducted with the associated collectors, wholesalers, and retailers, each of whom had a sample population of 5–10 respondents.

The primary data essential for this study was gathered by adopting various research instruments like, pre-pilot field visit, questionnaire survey, Focus Group Discussion (FGD), Key Informants' Interview (KII), Rapid Market Analysis (RMA), and case studies. The study involved administering a questionnaire survey to farmers, wholesalers, collectors, and retailers in the targeted group to gather information on production, marketing structure, and prices in the region. FGDs were conducted with farmers and wholesale suppliers to gather prices and margins of major vegetables. In order to gain insights into the current scenario of vegetable cultivation, yield statistics, farming participation, marketing structure, and economics, KIIs were conducted with progressive farmers, representatives of farmer and women groups, as well as local leaders and market representatives. RMA was performed to assess the market potential of vegetables by surveying local vegetable grocers on quantity, pricing mechanisms, price stability, and demand and supply. Additionally, case studies of successful vegetable farmers in the area were conducted to identify pricing strategies specific to the study area.

In order to supplement the primary data, various published and unpublished secondary sources of data, articles, reports, and proceedings published by various institutions and organizations like Nepal Agriculture Research Council (NARC), Central bureau of statistics (CBS), Agro-Enterprise Center (AEC), District Agriculture Development Office (DADO), Ministry of Agriculture and Livestock Development (MoALD), etc. were consulted. The collected data has been analyzed using appropriate qualitative and quantitative analysis techniques. Qualitative data from FGDs and KIIs has been transcribed, coded, and thematically analyzed to identify patterns, themes, and trends related to the seasonal flow of vegetables. Quantitative data from surveys of wholesale suppliers, retailers, and farmers has been entered into statistical software like MS Excel and SPSS (Statistical Package for Social Sciences) for data cleaning and analysis. Descriptive statistics, inferential statistics, and quantitative analysis techniques have been employed to analyze the quantitative data and present them using appropriate tables and charts. The findings from the data analysis have been interpreted and discussed in light of the research questions and existing literature.

PRICE ELASTICITY OF DEMAND & PRICE FLEXIBILITY

In a wholesale market, the trade volume is typically demand-guided rather than supply-guided. The quantity of vegetables traded in the market is primarily determined by the demand from buyers such as retailers, restaurants, and consumers. Suppliers or wholesalers respond to this demand by adjusting their supply levels accordingly (Houck, 1965). Price elasticity of demand (PED) is a measure of the responsiveness of the quantity demanded of vegetables in a wholesale market to changes in their prices. It quantifies how sensitive the demand for vegetables is to variations in price. The formula for price elasticity of demand is calculated by dividing the percentage change in quantity demanded by the percentage change in price. A higher value of price elasticity (>1) indicates a greater responsiveness of demand to price changes (elastic), while a lower value (<1) suggests a less responsive demand (inelastic). Understanding the price elasticity of demand for vegetables in a wholesale market is essential for market participants to anticipate the impact of price fluctuations on demand and adjust their strategies accordingly. Policymakers can also utilize this information to make informed decisions regarding pricing policies and market regulations to ensure a well-functioning vegetable market that meets consumer demands effectively.

The relationship between the estimated demand and supply coefficients has been thoroughly studied, but the literature does not clearly address the connection between direct price flexibility and demand elasticity. Even though it is frequently mentioned in passing, this specific relationship is still unclear. However, it only requires a little matrix algebra and economic theory to make it clear. Here, it is demonstrated that the reciprocal of direct price flexibility—often approximated in econometric work—is the lower absolute limit of the related direct price elasticity under fairly common circumstances. The strength of the cross effects of commodity substitution and, if applicable, complementarity, determine the difference between the two [6].

$$P.F.(F) = Inv.of\ P.E.(E^{-1})$$

$$F.E = I, where\ I\ is\ Identity\ Matrix$$

$$F_{11}E_{11} + \sum_{k=2}^{n} F_{1k}E_{1k} = 1$$

If two or more commodities are independent, then the inner product terms will be zero. Since, all terms of the equation but the first are negative or zero:

$$F_{11}E_{11} \geq 1 \qquad or, \qquad |E_{11}| \geq \left|\frac{1}{F_{11}}\right|$$

SEASONAL VARIATIONS AND SEASONALITY INDEX (SI)

As the marketing year passes on, there are relative variations in supply and demand, which cause crop prices to generally follow a seasonal trend. Typically, crop prices fall to their seasonal low at harvest and then rise again afterward. Postharvest rallies happen as a result of the crop's fixed supply being steadily depleted by consumption, which drives up prices. Seasonality is a phenomenon that lasts for a crop's entire production cycle, which is typically twelve months. Different from cyclical or trend forces are seasonal forces. One particular kind of cycle is a seasonal one. A cycle is an ongoing, self-sustaining pricing pattern that can happen at any time. Although there is some evidence that cycles have an impact on the livestock market, there is little other than "technical analysis" to suggest that other cycles have an impact on crops. Crop prices may act in a "contra-seasonal" way as a result of significant market shocks (droughts, embargoes, dramatic policy events, etc.). As a result, some analysts distinguish between years that had a unique "condition" and create seasonal models that only include such years.

The Seasonality Index (SI) is a measure used to analyze the seasonal pattern of price fluctuations for a particular product, such as vegetables. It helps identify the degree of seasonality or variation in prices throughout the year. To calculate the SI, the monthly average prices of vegetables over a specified period are used. The process of calculating the SI for wholesale vegetable prices involves the following steps. First, data is collected on the monthly average prices of selected vegetables over a specific time period. Next, the overall average price for each vegetable is calculated by summing up the monthly average prices and dividing them by the number of months. Then, the monthly price variation for each vegetable is determined by dividing the monthly average price by the overall average price. Finally, the SI is obtained by averaging the seasonal variations across all the vegetables, providing an overall index value that represents the relative degree of seasonality in wholesale vegetable prices. This index helps to identify the extent of price fluctuations and seasonality patterns in the market.

The value of SI is typically expressed as a percentage or a value ranging from 0 to 1. A higher index value indicates a higher degree of seasonality, meaning that the prices of the vegetables exhibit significant fluctuations throughout the year. Conversely, a lower index value suggests a more stable price pattern with less pronounced seasonal variations. The SI provides valuable insights into the seasonal behavior of vegetable prices, enabling farmers, traders, and policymakers to make informed decisions regarding production, marketing, and pricing strategies.

III. RESULTS AND DISCUSSIONS

The Price Flexibility Coefficient (PFC) and Seasonality Index (SI) analysis are econometric approaches commonly used to analyze the seasonal flow of vegetables. These techniques provide quantitative measures to understand the relationship between price and demand variations over different time periods. The PFC measures the responsiveness of quantity demanded to change in price. It helps determine the degree of elasticity or inelasticity of demand, indicating how sensitive consumers are to price fluctuations. A negative coefficient suggests that an increase in price leads to a decrease in demand, indicating price elasticity.

The SI, on the other hand, measures the seasonal variations in price or demand. It allows for the identification of patterns, trends, and cycles that occur at specific times of the year. By calculating the average seasonal variations across different months, the SI provides an overall measure of the relative degree of seasonality. By employing these econometric approaches, analysts can gain valuable insights into the seasonal flow of vegetables, understand the price-demand dynamics, identify peak and off-peak seasons, and make informed decisions regarding production, pricing, and market strategies. These techniques provide a quantitative framework to study and analyze the seasonal patterns in the vegetable market.

PRICE FLEXIBILITY OF TOMATO

Analysis of the PFCs for tomatoes in FY 2021/22 reveals interesting patterns. The negative coefficients for Jul/Aug, Aug/Sep, Sep/Oct, Jun/Jul, and May/Jun indicate that tomato prices are relatively flexible during these periods. A negative coefficient suggests that a percentage change in quantity demanded leads to a greater percentage change in price in the opposite direction. This implies that tomato prices are sensitive to changes in demand during these months.

On the other hand, the positive coefficients for Oct/Nov, Nov/Dec, Dec/Jan, Feb/Mar, and Mar/Apr indicate a relatively inelastic price response. A positive coefficient suggests that a percentage change in quantity demanded results in a smaller percentage change in price in the same direction. This indicates a lower sensitivity of tomato prices to changes in demand during these months. Notably, the coefficient for Apr/May stands out significantly with a large negative value of -26.22, which indicates a highly elastic price response to changes in quantity demanded during this period. A small change in demand could lead to a significant price fluctuation. This suggests that April to May is a critical time for tomato prices, where small shifts in demand can have a substantial impact on prices.

PRICE FLEXIBILITY OF POTATO

The negative coefficients observed for the months of Jul/Aug to Nov/Dec, Jan/Feb, Feb/Mar, and May/Jun suggest an inverse relationship between the price and demand for these periods, indicating a certain degree of price elasticity. Specifically, the harvesting season of potatoes in the mid-hills (Aug-Nov) and terai regions (Sep-Oct) of Nepal results in an abundance of supply, leading to market-driven prices during these months. Contrarily, positive coefficients in Dec/Jan, Mar/Apr, and Jun/Jul indicate an equilibrated or inelastic relationship between price and demand, wherein higher prices are accompanied by higher demand. Remarkably, the severe negative coefficient of -26.22 for the period Apr/May jumps out, demonstrating a sharp decline in demand as prices rise. The close to zero coefficients, as in Feb/Mar, indicate that price increases have little effect on demand during certain months.

Table 1: Price Flexibility Coefficient (PFC) of Major Vegetables in Kathmandu Valley

FY 2021/22 & 2020/21	Price Flexibility Coefficient				
	Tomato	Potato	Onion	Cauliflower	Cucumber
Jul/Aug	-0.35	-1.05	1.57	-0.32	-0.11
Aug/Sep	-0.43	-1.62	-0.01	-0.12	0.08
Sep/Oct	-0.29	-1.46	-0.24	-0.15	0.15
Oct/Nov	1.54	-0.98	-0.61	2.33	-0.11
Nov/Dec	14.05	-0.76	-0.80	-0.83	-0.38
Dec/Jan	2.47	0.63	-0.42	-2.57	1.14
Jan/Feb	-8.18	-0.66	-0.82	-1.88	0.01
Feb/Mar	1.19	-0.01	-0.81	2.16	2.71
Mar/Apr	3.40	0.24	0.56	-1.86	-0.52
Apr/May	-26.22	2.92	-0.72	-3.00	-0.37
May/Jun	-10.41	-0.62	-0.62	-30.32	-0.62
Jun/Jul	-1.08	0.62	-0.91	0.14	3.83

PRICE FLEXIBILITY OF ONION

The PFCs for onion reveal intriguing patterns that shed light on the unique dynamics of this market. In contrast to the high positive coefficient of 1.57 observed in Jul/Aug, indicating an inelastic demand, the negative coefficients observed in all other months suggest a potential for price-induced demand. However, it is important to note that the magnitude of these coefficients implies that even substantial price reductions do not have a significant impact on increasing demand. This finding underscores the overall inelastic nature of onion demand, which can be attributed to various factors such as consumer preferences, market conditions, and the dominant import market from China, which plays a pivotal role in the supply chain.

Additionally, the month of Jul/Aug presents an appealing dynamic as the monsoon season poses challenges for preserving the product, leading to quick spoilage and damage. This further contributes to the reduced responsiveness of consumers to price changes during this period.

PRICE FLEXIBILITY OF CAULIFLOWER

Cauliflower exhibits significant variations in price flexibility coefficients, indicative of its highly seasonal characteristics. Particularly, the months of Jan/Feb, Feb/Mar, and Mar/Apr exhibit relatively high positive coefficients of 2.16, 2.33, and 2.16, respectively, indicating a strong positive relationship between price and demand during these months. This aligns with the fact that January to March is the harvesting season for cauliflower in Nepal, when local supply is abundant, and prices are typically lower. Conversely, the negative coefficients observed in Jul/Aug, Aug/Sep, Sep/Oct, Nov/Dec, and May/Jun suggest a decrease in demand with increasing prices. Interestingly, May/Jun stands out with a remarkably negative coefficient of -30.32, indicating a highly elastic demand during this period. This can be attributed to the off-season for cauliflower, when local supply is scarce, and prices are typically higher due to reliance on imported cauliflower. These findings highlight the significance of seasonality in shaping the price-demand dynamics of cauliflower in Nepal.

PRICE FLEXIBILITY OF CUCUMBER

With its harvesting season spanning from April to November, cucumber experiences distinct shifts in demand throughout the year. Positive coefficients, such as 1.14 and 3.83, indicate a relatively inelastic demand during the peak months of the harvest season, suggesting that price variations have a limited impact on consumer behavior. On the other hand, negative coefficients, like -0.11 and -0.38 in the months of Oct/Nov and Nov/Dec respectively, imply a more elastic demand during end of the harvesting periods, indicating that consumers are more responsive to price changes. These findings shed light on the seasonal dynamics of the cucumber market in KV, emphasizing the importance of considering the specific timeframes and factors influencing consumer preferences and market conditions.

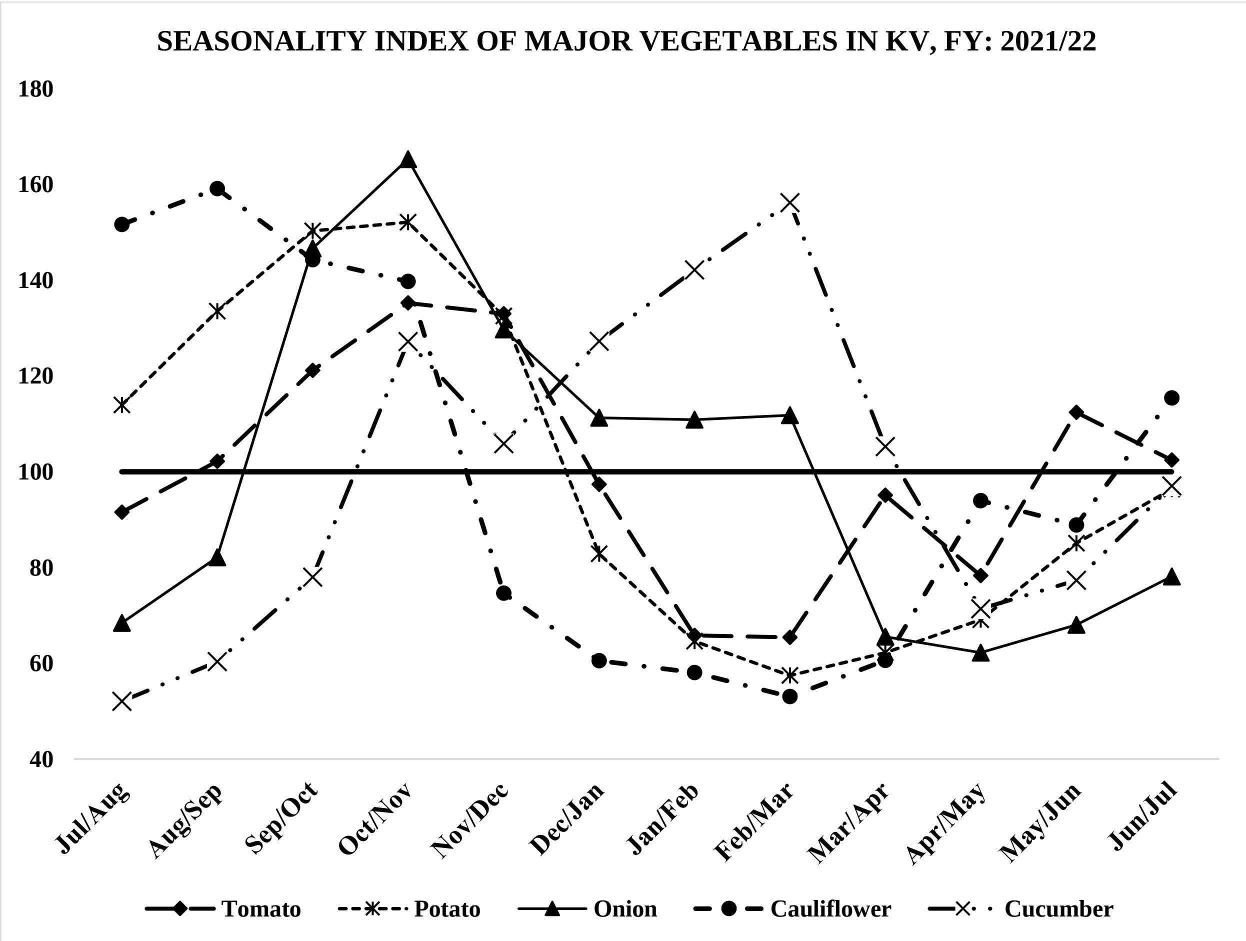

Fig.1: Seasonality Index (SI) of Major Vegetables in Kathmandu Valley

SEASONALITY OF VEGETABLES

The analysis of SI for the primary vegetables in Fiscal Year 2021/22 uncovers captivating trends in the variations of prices over the course of the year. Among the vegetables, Cauliflower exhibits the highest seasonality among vegetables, with a significant variation in prices across different months. It reaches its peak in Oct/Nov with a Seasonality Index of 165, indicating a substantial increase in prices during that period. Cucumber follows a similar trend, showing notable price fluctuations, reaching its highest index of 156 in Feb/Mar.

Onion, although exhibiting moderate seasonality, shows a consistent increase in prices from Sep/Oct to Nov/Dec, with a peak Seasonality Index of 165. This suggests that onion prices tend to rise during the later part of the year. Tomato and Potato demonstrate relatively lower seasonality compared to the other vegetables. Tomato prices exhibit a slight decline in the early months, reaching the lowest Seasonality Index of 65 in Feb/Mar, before gradually increasing again towards the end of the fiscal year. Similarly, Potato prices remain relatively stable throughout the year, with a slight dip in Dec/Jan.

Table 2: Analysis of Seasonality of Major Vegetables in Kathmandu Valley

Vegetable	Analysis of Seasonality Data	Growing Season [12]
Tomato	Low Seasonality; Slight decline of SI to 65 during Feb/Mar.	All Year Round
Potato	Low Seasonality; Slight decline of SI to 57 during Feb/Mar.	All Year Round
Onion	Moderate Seasonality; Consistent increase in price from Sep/Oct to Oct/Nov	All Year Round
Cauliflower	Highest Seasonality; Peak SI 165 during the month Oct/Nov	January- March
Cucumber	High Seasonality; SI 156 during the month Feb/Mar	April- November

Tomato and Potato, being year-round crops, exhibit relatively lower seasonality in terms of price fluctuations. This aligns with their continuous availability throughout the year, as indicated by the SI. Their steady supply contributes to a more stable price trend, with minor variations observed during certain months.

On the other hand, Onion, despite being a year-round crop, experiences production and storage challenges during the rainy (monsoon) season in June/July and July/August. This aligns with the notable dip in prices during those months, as reflected in the SI. The adverse weather conditions during the monsoon season can hamper the onion production and quick spoilage (rotting) due to high relative humidity, leading to reduced supply and also the demand (poor quality product) and subsequently lower prices in the market.

Cauliflower has a specific growing season from January to March, which coincides with its highest SI during that period. The limited availability of cauliflower outside this Period contributes to higher prices, as demand outpaces supply. The concentrated production season of cauliflower explains its pronounced price fluctuations during the specified months. Cucumber, with a growing season from April to November, exhibits a high level of seasonality. Its prices remain relatively stable during the growing season, aligning with its higher availability in the market. However, as the season ends in November, there is a decline in supply, leading to increased prices.

Overall, the comparison between the SI and the growing seasons of vegetables supports the argument that the availability and production patterns play a significant role in price fluctuations. Year-round crops like tomato and potato, with continuous availability, experience lower seasonality. Vegetables with specific growing seasons, such as cauliflower and cucumber, demonstrate higher seasonality due to the limited supply during certain months. The challenges faced during the monsoon season also impact the production, storage, and prices of onions. This analysis highlights the importance of understanding the interplay between growing seasons, supply, and market dynamics in explaining the observed variations in vegetable prices. Farmers, traders, and consumers can utilize this information to make informed decisions regarding production planning, procurement, and pricing strategies.

IV. CONCLUSION AND RECOMMENDATIONS

Overall, the demand for tomatoes exhibits mixed elasticity, with relatively inelastic demand during the months of November to March, as indicated by the positive coefficients. However, during the months of April to June, the price flexibility coefficients are highly negative, indicating a more elastic demand. In the meantime, potatoes appear to be predominantly inelastic overall, with limited responsiveness to price changes during the months of July and August. Similarly, onions show mixed elasticity patterns, with demand inelasticity during the months of July to October and flexibility during the months of November to April, suggesting a more elastic demand. Based on the import model and the risk of being spoiled during monsoon seasons, onions show reduced consumer responsiveness to price changes during July and August, which is the critical period for them. On the other hand, cauliflower, and cucumber, being seasonal crops, demonstrate high inelasticity during harvesting season due to the surplus flow of the product into the market and comparatively elastic demand during off-seasons and pre-harvesting periods.

The study also indicates high seasonality in the prices of cauliflower and cucumber, which are inherently seasonal crops, during pre-harvesting and off-season periods. Onions exhibit moderate seasonality in prices, with a consistent price increment from September to November. This price hike aligns with the occurrence of the country's biggest festivals, Dashain and Tihar, which justifies the increase. Lastly, potato and tomato, being year-round crops, show low seasonality, with a slight decline in the seasonality index during the months of February and March.

Considering a relatively inelastic demand from the results of this study and the import share of vegetables in Kathmandu Valley, which stands at around 40% in FY 2021/22, it becomes crucial to explore strategies for reducing dependency on imports. In line with this, one of the key recommendations is to prioritize increasing domestic production of vegetables. This can be achieved by providing support and incentives to local farmers, including access to quality seeds, modern farming techniques, and agricultural training programs. By enhancing domestic production, the valley can reduce its reliance on imported vegetables and create a more sustainable and self-sufficient market. Furthermore, it is essential to improve post-harvest infrastructure to minimize spoilage and optimize the supply chain. This includes investing in storage facilities, transportation networks, and cold chain infrastructure. By ensuring that vegetables are properly handled, stored, and transported, the overall quality and marketability of the produce can be maintained, reducing wastage and losses.

In addition to these measures, enhancing market efficiency is crucial. This involves streamlining supply chains, reducing intermediaries, and establishing transparent pricing mechanisms. By creating a more competitive and fair market environment, farmers can receive better returns for their produce, while consumers can access vegetables at reasonable prices. To counter the inelastic demand, promoting value addition in vegetables can be an effective strategy. This can include processing, packaging, and branding initiatives that add value to the produce. Value-added products can command higher prices and open up opportunities for market expansion, both domestically and internationally.

Supporting research and development activities in the vegetable sector is another recommendation. By investing in R&D, improved varieties of vegetables can be developed that are better suited to local conditions, have higher yields, and exhibit desirable traits. This can contribute to increased productivity and competitiveness in the market.

Lastly, collaboration and networking among stakeholders in the vegetable supply chain are essential. This includes fostering partnerships between farmers, traders, retailers, and policymakers to share knowledge, coordinate efforts, and collectively address challenges. By working together, stakeholders can leverage their expertise and resources to drive market efficiency and enhance the overall performance of the vegetable sector.

While these recommendations focus on increasing domestic production, improving market efficiency, and promoting value addition, it is important to consider the implications for imports. As the domestic production capacity improves, the need for imports can potentially be reduced. However, a comprehensive analysis of import dynamics, market demands, and trade policies would be necessary to devise strategies for reducing imports effectively and ensuring a balanced market supply.

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APPENDICES

Table 3: Calculation of Price Elasticity and Price Flexibility Coefficient for Tomatoes in Kathmandu Valley

	FY 2021/22		FY 2020/21		Price Elasticity	Price Flexibility Coefficient
	Supply Quantity (MT)	Price (Rs. /kg)	Supply Quantity (MT)	Price (Rs. /kg)		
Jul/Aug	1,937.007	42.395	1,189.454	54.384	-2.85	-0.35
Aug/Sep	2,156.515	37.248	1,029.055	70.790	-2.31	-0.43
Sep/Oct	1,771.546	58.458	1,136.768	69.623	-3.48	-0.29
Oct/Nov	1,845.615	74.958	1,730.848	68.008	0.65	1.54
Nov/Dec	2,114.606	87.602	2,020.627	52.988	0.07	14.05
Dec/Jan	3,036.624	57.843	2,723.745	45.063	0.41	2.47
Jan/Feb	2,942.799	40.193	3,081.824	29.357	-0.12	-8.18
Feb/Mar	4,022.442	40.698	2,954.501	28.455	0.84	1.19
Mar/Apr	4,817.369	58.024	4,348.795	42.473	0.29	3.40
Apr/May	3,329.184	53.533	3,437.657	29.293	-0.04	-26.22
May/Jun	2,075.915	85.715	2,449.883	33.113	-0.10	-10.41
Jun/Jul	1,380.103	61.014	1,886.379	47.288	-0.92	-1.08

Table 4: Calculation of Price Elasticity and Price Flexibility Coefficient for Potatoes in Kathmandu Valley

	FY 2021/22		FY 2020/21		Price Elasticity	Price Flexibility Coefficient
	Supply Quantity (MT)	Price (Rs. /kg)	Supply Quantity (MT)	Price (Rs. /kg)		
Jul/Aug	5,928.153	39.905	4,717.026	54.643	-0.95	-1.05
Aug/Sep	5,643.250	43.233	4,617.754	67.577	-0.62	-1.62
Sep/Oct	5,755.263	45.965	4,475.370	78.740	-0.69	-1.46
Oct/Nov	5,281.811	50.875	3,963.549	75.363	-1.02	-0.98
Nov/Dec	6,154.875	41.738	4,076.638	68.233	-1.31	-0.76
Dec/Jan	4,433.812	30.475	6,560.119	38.267	1.59	0.63
Jan/Feb	5,377.781	28.047	6,312.881	25.563	-1.52	-0.66
Feb/Mar	5,086.861	23.813	4,134.738	23.850	-146.45	-0.01
Mar/Apr	3,490.822	25.100	4,464.752	26.513	4.09	0.24
Apr/May	2,784.802	26.563	2,921.749	30.777	0.34	2.92
May/Jun	3,527.574	33.003	2,945.779	37.573	-1.62	-0.62
Jun/Jul	5,063.815	40.893	4,709.864	39.065	1.61	0.62

Table 5: Calculation of Price Elasticity and Price Flexibility Coefficient for Onions in Kathmandu Valley

	FY 2021/22		FY 2020/21		Price Elasticity	Price Flexibility Coefficient
	Supply Quantity (MT)	Price (Rs. /kg)	Supply Quantity (MT)	Price (Rs. /kg)		
Jul/Aug	3,122.514	46.820	2,378.663	31.380	0.64	1.57

Aug/Sep	2,984.926	46.760	1,441.313	47.180	-120.31	-0.01
Sep/Oct	2,158.204	60.760	775.895	106.910	-4.13	-0.24
Oct/Nov	2,311.387	65.100	1,298.772	123.870	-1.64	-0.61
Nov/Dec	2,747.225	49.540	1,690.010	98.790	-1.25	-0.80
Dec/Jan	3,289.930	55.020	2,099.660	72.170	-2.39	-0.42
Jan/Feb	2,817.096	57.600	2,339.024	69.160	-1.22	-0.82
Feb/Mar	3,166.786	58.340	2,644.090	69.460	-1.23	-0.81
Mar/Apr	3,170.892	36.480	3,489.714	38.450	1.78	0.56
Apr/May	3,009.148	33.560	2,618.706	37.580	-1.39	-0.72
May/Jun	2,871.194	33.280	2,044.148	44.470	-1.61	-0.62
Jun/Jul	3,294.556	39.110	2,651.441	50.190	-1.10	-0.91

Table 6: Calculation of Price Elasticity and Price Flexibility Coefficient for Cauliflower in Kathmandu Valley

	FY 2021/22		FY 2020/21		Price Elasticity	Price Flexibility Coefficient
	Supply Quantity (MT)	Price (Rs. /kg)	Supply Quantity (MT)	Price (Rs. /kg)		
Jul/Aug	679.622	79.340	355.636	111.380	-3.17	-0.32
Aug/Sep	995.312	85.930	325.325	114.210	-8.32	-0.12
Sep/Oct	1,628.841	83.330	819.309	98.160	-6.54	-0.15
Oct/Nov	1,297.834	99.060	1,153.328	76.685	0.43	2.33
Nov/Dec	2,217.312	47.563	2,294.547	46.273	-1.21	-0.83
Dec/Jan	2,069.130	43.440	2,371.522	32.730	-0.39	-2.57
Jan/Feb	1,393.554	45.293	2,098.100	27.743	-0.53	-1.88
Feb/Mar	2,290.494	37.563	2,019.613	29.127	0.46	2.16
Mar/Apr	1,616.234	24.287	1,257.152	51.933	-0.54	-1.86
Apr/May	922.734	66.375	1,017.906	51.817	-0.33	-3.00
May/Jun	760.877	67.865	774.822	43.905	-0.03	-30.32
Jun/Jul	944.589	76.775	496.832	68.380	7.34	0.14

Table 7: Calculation of Price Elasticity and Price Flexibility Coefficient for Cucumber in Kathmandu Valley

	FY 2021/22		FY 2020/21		Price Elasticity	Price Flexibility Coefficient
	Supply Quantity (MT)	Price (Rs. /kg)	Supply Quantity (MT)	Price (Rs. /kg)		
Jul/Aug	1,488.281	26.185	718.338	29.600	-9.29	-0.11
Aug/Sep	1,516.837	32.795	1,122.612	31.855	11.90	0.08
Sep/Oct	1,543.072	43.645	943.509	39.905	6.78	0.15
Oct/Nov	832.454	66.970	627.912	69.345	-9.51	-0.11
Nov/Dec	878.869	41.420	415.840	72.020	-2.62	-0.38
Dec/Jan	468.689	78.350	358.180	58.005	0.88	1.14
Jan/Feb	333.750	76.215	295.075	76.115	99.76	0.01

Feb/Mar	392.805	90.055	370.345	77.360	0.37	2.71
Mar/Apr	1,407.655	49.995	1,008.484	62.800	-1.94	-0.52
Apr/May	1,959.045	28.005	916.954	48.510	-2.69	-0.37
May/Jun	792.727	37.530	619.962	45.295	-1.63	-0.62
Jun/Jul	688.550	64.865	587.690	39.145	0.26	3.83

Table 8: Calculation of Seasonality Index for Tomatoes in Kathmandu Valley

Months	Price (Rs. /Kg for FY 2021/22)	Price (Rs. /Kg for FY 2020/21)	Monthly Average	Seasonal Index
Jul/Aug	42.395	54.384	48.390	91.55
Aug/Sep	37.248	70.790	54.019	102.20
Sep/Oct	58.458	69.623	64.040	121.16
Oct/Nov	74.958	68.008	71.483	135.24
Nov/Dec	87.602	52.988	70.295	133.00
Dec/Jan	57.843	45.063	51.453	97.35
Jan/Feb	40.193	29.357	34.775	65.79
Feb/Mar	40.698	28.455	34.577	65.42
Mar/Apr	58.024	42.473	50.249	95.07
Apr/May	53.533	29.293	41.413	78.35
May/Jun	85.715	33.113	59.414	112.41
Jun/Jul	61.014	47.288	54.151	102.45
Average	58.140	47.570	52.855	

Table 9: Calculation of Seasonality Index for Potatoes in Kathmandu Valley

Months	Price (Rs. /Kg for FY 2021/22)	Price (Rs. /Kg for FY 2020/21)	Monthly Average	Seasonal Index
Jul/Aug	39.905	54.643	47.274	113.94
Aug/Sep	43.233	67.577	55.405	133.54
Sep/Oct	45.965	78.740	62.353	150.28
Oct/Nov	50.875	75.363	63.119	152.13
Nov/Dec	41.738	68.233	54.985	132.53
Dec/Jan	30.475	38.267	34.371	82.84
Jan/Feb	28.047	25.563	26.805	64.61
Feb/Mar	23.813	23.850	23.831	57.44
Mar/Apr	25.100	26.513	25.807	62.20
Apr/May	26.563	30.777	28.670	69.10
May/Jun	33.003	37.573	35.288	85.05
Jun/Jul	40.893	39.065	39.979	96.36
Average	35.801	47.180	41.490	

Table 10: Calculation of Seasonality Index for Onions in Kathmandu Valley

Months	Price (Rs. /Kg for FY 2021/22)	Price (Rs. /Kg for FY 2020/21)	Monthly Average	Seasonal Index
Jul/Aug	46.820	31.380	39.100	68.40
Aug/Sep	46.760	47.180	46.970	82.16
Sep/Oct	60.760	106.910	83.835	146.65
Oct/Nov	65.100	123.870	94.485	165.28
Nov/Dec	49.540	98.790	74.165	129.74
Dec/Jan	55.020	72.170	63.595	111.25
Jan/Feb	57.600	69.160	63.380	110.87
Feb/Mar	58.340	69.460	63.900	111.78
Mar/Apr	36.480	38.450	37.465	65.54
Apr/May	33.560	37.580	35.570	62.22
May/Jun	33.280	44.470	38.875	68.00
Jun/Jul	39.110	50.190	44.650	78.11
Average	48.531	65.801	57.166	

Table 11: Calculation of Seasonality Index for Cauliflower in Kathmandu Valley

Months	Price (Rs. /Kg for FY 2021/22)	Price (Rs. /Kg for FY 2020/21)	Monthly Average	Seasonal Index
Jul/Aug	79.340	111.380	95.360	151.65
Aug/Sep	85.930	114.210	100.070	159.14
Sep/Oct	83.330	98.160	90.745	144.31
Oct/Nov	99.060	76.685	87.873	139.74
Nov/Dec	47.563	46.273	46.918	74.61
Dec/Jan	43.440	32.730	38.085	60.57
Jan/Feb	45.293	27.743	36.518	58.07
Feb/Mar	37.563	29.127	33.345	53.03
Mar/Apr	24.287	51.933	38.110	60.61
Apr/May	66.375	51.817	59.096	93.98
May/Jun	67.865	43.905	55.885	88.87
Jun/Jul	76.775	68.380	72.578	115.42
Average	63.068	62.695	62.882	

Table 12: Calculation of Seasonality Index for Cucumber in Kathmandu Valley

Months	Price (Rs. /Kg for FY 2021/22)	Price (Rs. /Kg for FY 2020/21)	Monthly Average	Seasonal Index
Jul/Aug	26.185	29.600	27.893	52.06
Aug/Sep	32.795	31.855	32.325	60.33
Sep/Oct	43.645	39.905	41.775	77.96

Oct/Nov	66.970	69.345	68.158	127.20
Nov/Dec	41.420	72.020	56.720	105.86
Dec/Jan	78.350	58.005	68.178	127.24
Jan/Feb	76.215	76.115	76.165	142.14
Feb/Mar	90.055	77.360	83.708	156.22
Mar/Apr	49.995	62.800	56.398	105.25
Apr/May	28.005	48.510	38.258	71.40
May/Jun	37.530	45.295	41.413	77.29
Jun/Jul	64.865	39.145	52.005	97.06
Average	53.003	54.163	53.583	

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Analysis of Land Use Evolution of Suzhou Wetlands Based on RS and GIS

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***Abstract*— The purpose of this study is to analyze the land use evolution and characteristics of Suzhou wetlands. Located in the Taihu Lake basin, Suzhou has abundant wetland resources, covering 339,500 hectares and accounting for 40% of the land area. The huge wetlands have high environmental and ecological indicators. With the support of RS and GIS technology, Landsat OLI 30 m remote sensing images, vector data, 30 m DEM, and other data are used. Through analysis and processing, land use type maps, wetland distribution maps, and research area overview maps are generated, and their land use area, dynamic degree, and transfer matrix are calculated. The results show that from 2013 to 2020, the total area of Suzhou wetlands showed a decreasing trend, with a total change of -8.77%. In the past seven years, Suzhou's urban construction rate has been relatively fast, and the main supply sources of construction land were lakes, mudflats, wetlands, and woodlands. Based on this, the impact of economic development and construction on the protection of environmental ecology should be emphasized and implemented in wetland management and protection strategies in order to promote sustainable environmental development.*
Keywords*— Land Use, Wetlands, Remote sensing (RS) & Geographic Information System (GIS), Transfer Matrix, Dynamic Degree.

I. INTRODUCTION

In the context of the modernization process of national development goals, the Yangtze River Delta is trying to integrate strategies to achieve a green economy, high-quality life, and sustainable development; deeply implement the concept of ecological civilization construction; adhere to ecological priority development; and promote social and economic development mutually. Based on this, the construction and practice of ecological civilization are increasingly valued, becoming the top priority of current urban and rural development.

Wetlands are one of the most abundant natural resources in the Yangtze River Delta, playing a crucial role in supporting national sustainable development and becoming one of the important subjects of regional ecological environment protection (Guo et al., 2017; Wang, 2022). From the perspective of national ecological security, that is, a country's ecological environment is relatively small or undamaged and is in a healthy and sustainable development state. Wetlands, as a unique ecosystem, can provide habitat for waterfowl and wildlife, improve biodiversity, and fully self-repair and regulate themselves.

They can also improve the ecological carrying capacity of the region to a certain extent, making them an important component of the national ecological security system. Among various ecosystems, wetlands are the most productive ecosystem in nature, possessing the characteristics of both wetland and terrestrial ecosystems. They play a crucial role in soil and water conservation, climate regulation, pollution degradation, and biodiversity protection and can maintain regional natural ecological balance and sustainable economic and social development, providing reliable guarantees for national ecological security. Therefore, conducting in-depth research and analysis on wetlands has important national strategic value and significance (Du, 2021; Yi, 2021).

This study mainly analyzes the land use evolution of Suzhou wetlands, explores the trend of wetland area evolution, and analyzes its influencing factors from a multi-level perspective, aiming to provide reference data for ecological security support for regional sustainable development. The research results will provide decision-making support for the protection and management of regional wetlands. The specific research objectives and methods are based on remote sensing image data by 2013 and 2020, using remote sensing (RS) and geographic information system (GIS) technology to analyze the dynamic trend of land use change (Liang and Wang, 2023; Zhang and Wang, 2023), analyze the changes in the value of wetland ecosystem services, and propose relevant strategies on this basis to provide suggestions for promoting the sustainable development of the ecological environment in the region.

II. LITERATURE REVIEW

2.1. Land Use and Wetlands

Land use refers to the way and purpose of human use of the natural attributes of land, and is a dynamic process. Its development and changes are influenced by natural, social, economic, and technological conditions, which collectively determine the function of land. The working group of the Land Use Planning Department of the Food and Agriculture Organization of the United Nations (FAO) pointed out that land use refers to the land function determined by natural conditions and human intervention. In the process, human beings manage land resources to fully utilize land functions while seeking better environmental quality, which is the core issue.

In the process of land use, economic benefits and ecological benefits have symbiosis and interdependence but may also generate exclusion. Because of land are an ecological and economic system that is coupled by the natural ecosystem of the land and the land economic system. In the process of land use activities or social production and reproduction, a certain amount of labor is occupied and consumed. Not only do we need to produce a certain amount of products that meet social needs (i.e., produce a certain economic effect), but we must also remove and inject some substances and energy, as well as some pollutants, from the land ecological system. In this process of 'taking' and 'returning', the land ecological and economic system undergoes significant changes, resulting in certain ecological benefits (Ge and Ma, 2022).

There are various definitions of wetlands, and currently the internationally recognized definition of wetlands is proposed by the Wetlands Convention, which refers to natural or artificial, permanent or temporary swamps, peatlands or water areas, static or flowing, fresh water, brackish water, and saline water bodies, including water bodies with a depth of no more than 6 meters at low tide. Wetlands include many types, including coral reefs, mudflats, mangroves, lakes, rivers, estuaries, marshes, reservoirs, ponds, rice fields, etc. Their common feature is that their surfaces are constantly covered or filled with water, forming a transitional zone between land and water bodies (Wu, 2022; Porras-Rojas et al., 2023).

Wetlands are widely distributed around the world and are a symbol of biodiversity on Earth, with rich and highly productive ecosystems. It plays an important role in resisting floods, regulating runoff, controlling pollution, regulating the climate, and beautifying the environment. It is not only a natural water storage reservoir on land but also a breeding and wintering ground for many wild animals and plants, especially rare waterfowl. It can provide water and food for humans. Its natural diversity function has become a precious resource possessed by humans; therefore, wetlands are also known as the "cradle of life", "kidney of the earth", and "paradise of birds" (Guo et al., 2017; Yi, 2022).

2.2 Progress in Wetland Research

The research progress of wetland land use has led to significant changes in the wetland ecological environment over time and with the development of society, as well as the natural geographical environment and human social activities. From the perspective of wetland types, the degradation of natural wetlands is significant; the scale of artificial wetlands continues to expand; wetland habitats are damaged; diversity decreases; and habitat fragmentation intensifies, thereby weakening the original functions of wetland ecosystems. From the perspective of land use types, wetlands are also constantly being replaced by construction land, resulting in environmental and human hazards. Therefore, in the natural and social context, research on the evolution of wetland land use has also received attention.

Against the aforementioned background, numerous scholars are committed to studying the spatio-temporal evolution of laws of land use. With the deepening of land use research, relevant principles and research methods have begun to be applied to wetland research. This study used the China National Knowledge Infrastructure (CNKI) to search for 915 papers related to wetland landscape patterns published between 1980 and 2023. Quantitative analysis (Figure 1) showed that research on wetland land use has shown a significant increase since the 21st century and is currently on a fluctuating upward trend. On the one hand, it reflects the maturity and improvement of wetland land use analysis technology and research methods due to the development of information technology. On the other hand, it also demonstrates the importance that scholars attach to ecological research such as wetland land use in the new context of continuous promotion. In addition, most scholars focus on the spatio-temporal evolution characteristics and internal and external driving mechanisms of dynamic changes in wetland land use research.

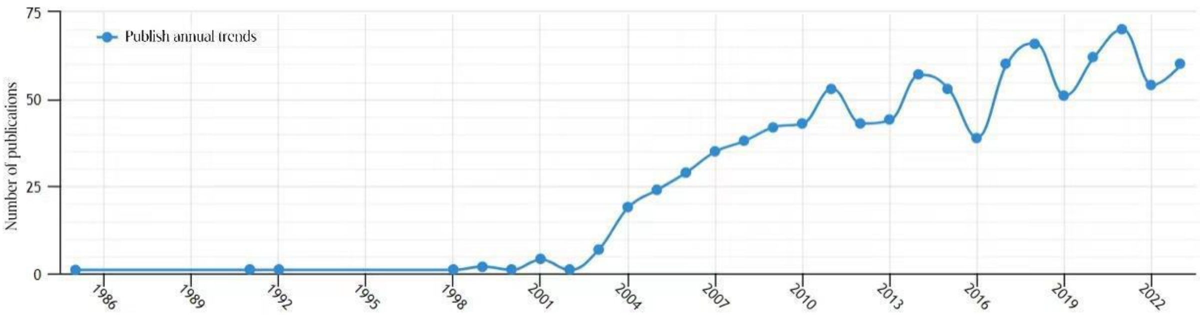

Fig.1: Trends in the number of publications related to Wetland Land Use (source: CNKI)

The research method for wetland land use mainly relies on existing land use analysis methods, using transfer matrix and dynamic degree analysis to quantify the dynamic change process and trend of wetland land use through indicators such as the area and size of the study area. In recent years, there has also been a focus on the use of RS technology, collecting and processing various types of RS images to obtain basic data (Guo et al., 2017; Jamali et al., 2021). Through RS classification and the use of GIS software, corresponding maps have been created for quantitative analysis of spatial data, and the dynamic change process of wetlands and their spatial differentiation patterns have been explored.

In addition, given the comprehensiveness and complexity of wetland ecosystems and land use, it is necessary for subsequent research to study the influencing factors of wetland land use evolution from a multidisciplinary perspective. The research on statistical wetland land use involves the display of disciplinary classification charts (Figure 2). Currently, research on wetland land use mostly involves multiple disciplinary categories, mainly focused on environmental science and resource utilization. Therefore, it is necessary to strengthen interdisciplinary communication and cooperation, study the optimization of wetland land use, and conduct quantitative analysis of influencing factors from a more diverse and accurate perspective, which is more conducive to comprehensive research and understanding.

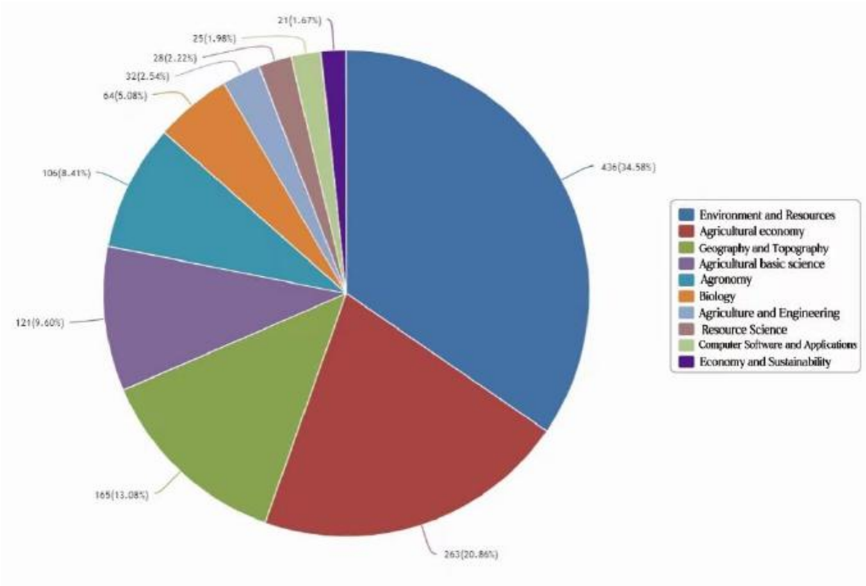

Fig.2 Distribution Map of Disciplines Involved in Wetland Land Use Research (Source: CNKI)

2.3 Research on Wetlands in Suzhou Area

Wetlands are known as the kidney of the earth, carbon storage, the resource pool of species, and the home of birds. Together with forests and oceans, they are called the three major ecosystems in the world and are one of the ecosystems with the strongest self-purification ability in the natural environment. Suzhou wetland protection closely focuses on the Yangtze River protection, the Yangtze River Delta integration, and the ecological protection strategic layout of the Taihu Lake. It promotes the goal of wetland protection and management and attempts to establish the "Suzhou model". The protection capacity has also been continuously valued and improved. The city has added 200,000 acres of newly protected wetlands, and the protection rates of natural wetlands and artificial wetlands have increased to 70.4% and 55.4%, respectively, ranking first in the province.

Given the importance of Suzhou wetlands and the complexity they exhibit with environmental changes, relevant scholars are continuously advancing and improving their research on wetlands, and the entry points for research are also being refined (Figure 3). Previous studies focused on the correlation between Suzhou Wetland Park and ecological restoration or on the study of wetland refinement types in the Taihu Lake basin of Jiangsu Province. Among them, there is relatively little research on breaking through provincial boundaries and analyzing the changes in wetland conditions in Suzhou from a holistic perspective. Therefore, in the context of implementing sustainable ecological protection strategies, exploring the impact of changes in the value of wetland ecosystem services in Suzhou will become a new perspective for wetland research (Wang, 2022).

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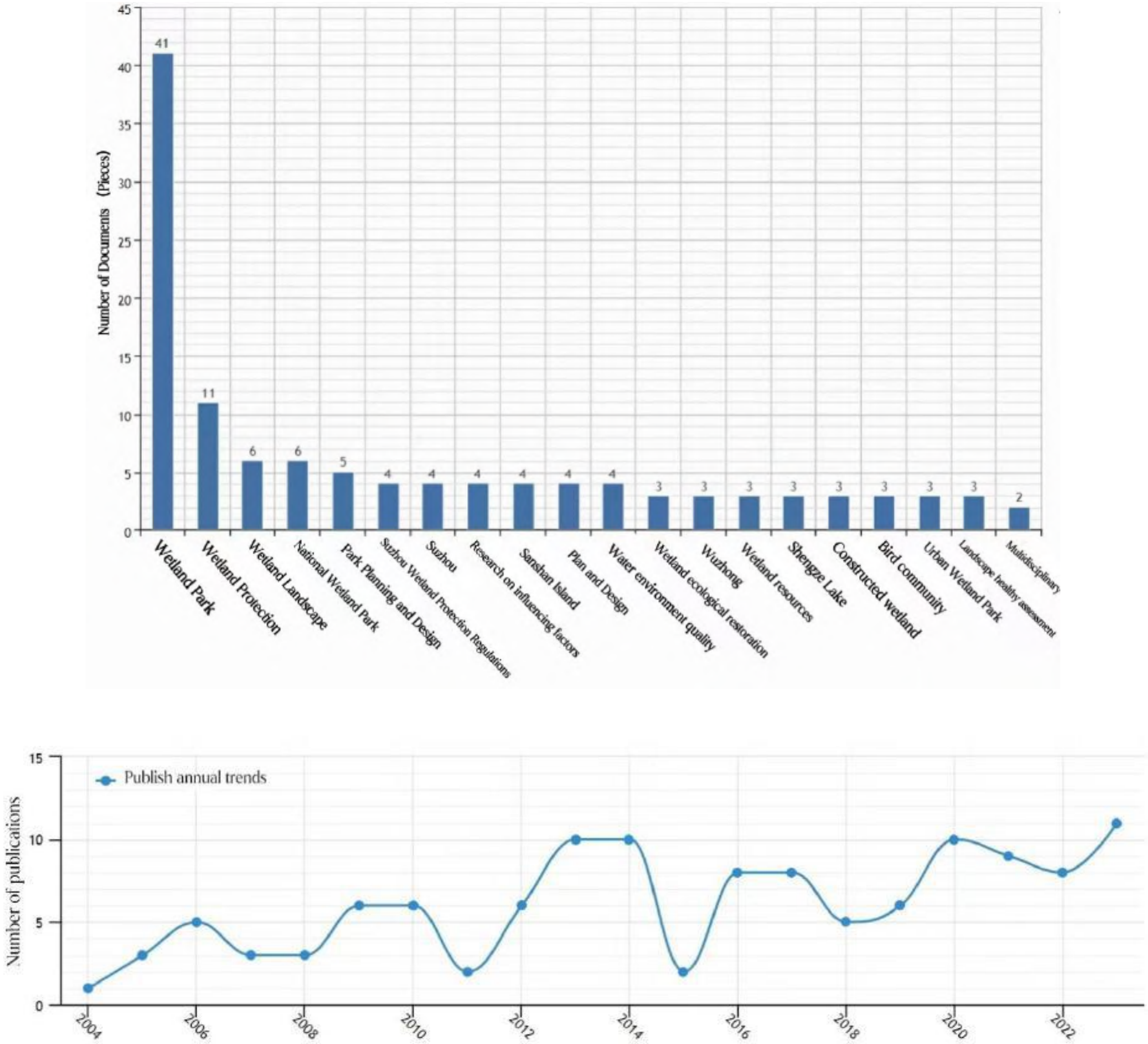


Fig.3 Trends and Theme Content of Literature on Wetland Research in Suzhou (Source: CNKI)

III. STUDY AREA

Suzhou is located in East China, the southeast of Jiangsu Province, the middle of the Yangtze River Delta, and the east bank of the Taihu Lake, bordering Shanghai in the east, Jiaxing City and Huzhou City in Zhejiang Province in the south, Wuxi City in the west, and the Yangtze River in the north, between 119° 55′ -121° 20′ E and 30° 47′ -32° 02′ N (Figure 4); the total area is 8657.32 km^2. The terrain of the city is low and flat. There are many rivers and lakes in the city. Most of the water surface of Taihu Lake is in Suzhou. The area of rivers, lakes, and mudflats accounts for 36.6% of the land area of the city. It is a famous water town in the south of the Yangtze River.

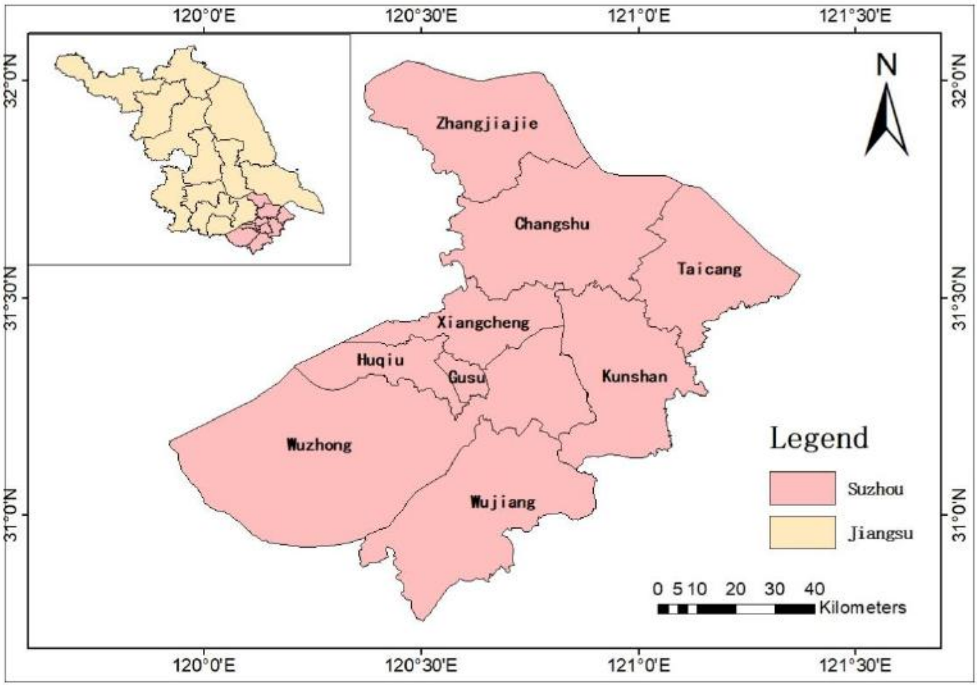
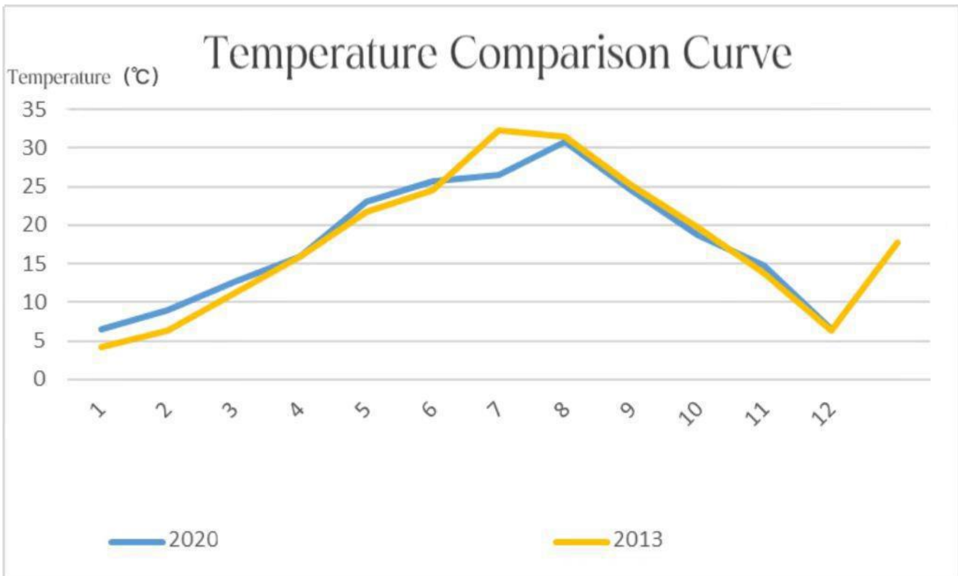


Fig.4 Map of Suzhou City

In terms of climate conditions, it is located in the humid monsoon climate zone of the northern subtropical zone, with warm, humid, and rainy weather. The monsoon is distinct and has four distinct seasons, with long winter and summer seasons and short spring and autumn seasons. The average annual frost-free period is 233 days. Due to the differences in terrain and latitude, various unique microclimates are formed in the territory. The Taihu Lake is the high center of solar radiation, sunshine, and temperature, and the areas along the river are the low value areas. The distribution of precipitation also follows the same pattern (Figure 5).

There is a significant correlation between climate change and wetland dynamics in Suzhou. Relative humidity and temperature are the main climate factors that affect the increase and decrease of wetlands, respectively. A warm and humid climate is an important factor leading to the increase of wetlands, while the decrease of wetlands is mainly related to the hot and dry climate. The different trends of climate change are important factors affecting wetland changes.



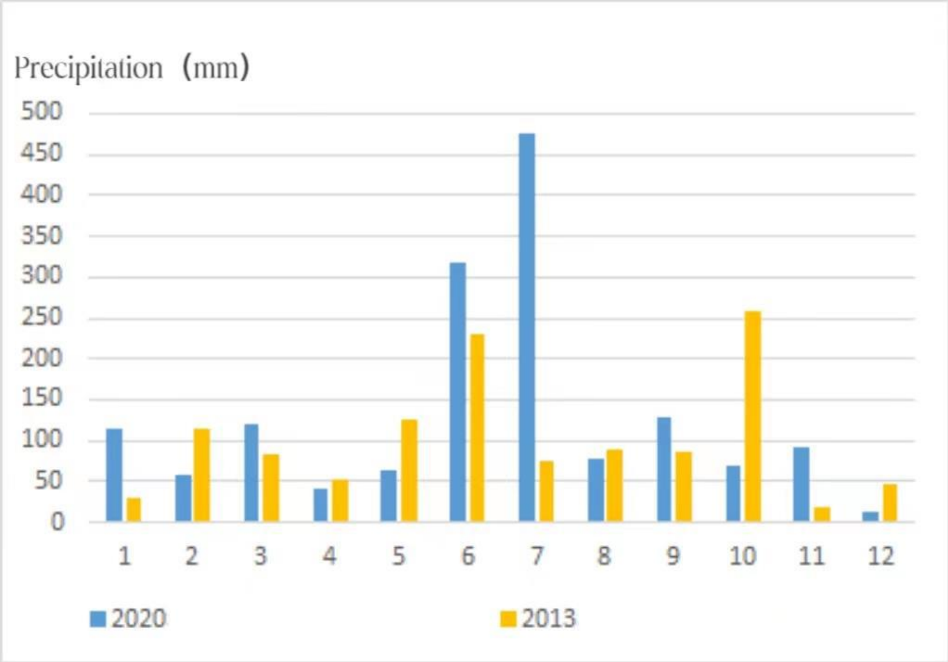


Fig.5 Comparison of temperature and rainfall in Suzhou

The average precipitation in Suzhou (1956~2000 series) is 1086.3 mm, which is equivalent to a total precipitation of more than 9 billion m^3; among them, 1999, the year with the most precipitation, averaged 1513.8 mm, and the average rainfall of plum rains was 630 mm, which is 3 times. The second was 1452.7 mm in 1993, and the least was 598.2 mm in 1978, with a difference of 2.53 times between abundance and dryness.

In 2022, Suzhou will achieve a regional GDP of 2,395.834 billion yuan, an increase of 2.0% over the previous year at comparable prices, of which the added value of the primary industry is 19.298 billion yuan, an increase of 3.0%. The secondary industry was 1,152.141 billion yuan, an increase of 1.8%. The tertiary industry was 1,224.395 billion yuan, an increase of 2.1%. The ratio of the three industrial structures is 0.8:48.1:51.1. Calculated by the permanent population, the per capita GDP was 186,000 yuan, an increase of 1.3% over the previous year. With the acceleration of urbanization, Suzhou's economy continues to develop, and construction land increases. How to coordinate the relationship between economic development and ecological protection is an important issue for sustainable development.

IV. MATERIAL AND METHOD

4.1 Data Source and Preprocessing

The research data sources include: (1) Landsat images in 2013 and 2020 were obtained from Geospatial Data Cloud (GDC) (https://www.gscloud.cn/sources/index?pid=1&rootid=1) (Table 1); (2) The verification data for Suzhou Wetland is sourced from the satellite map of the Eight-Nine Network; (3) Average precipitation, annual average temperature, and population data for the two periods were acquired from Yearbook Statistics.

Table 1 Information of Remote Sensing Images

SN	Satellite	Sensor	Track Number	Acquire time	Resolution（m）
1	Landsat-8	OLI	119/039	2013.7.19	30
2	Landsat-8	OLI	119/038	2020.5.03	30

In addition, data preprocessing involves radiometric calibration, atmospheric correction, and mosaic clipping of two Landsat-8 images to obtain the image area of the study area. According to the "Overall Plan for Land Use in Jiangsu Province" and the "Technical Regulations for Land Use Status Survey", referring to the national classification standards and Yancheng City's land use status, the landscape types in the research area are divided into four categories, including construction land (urban and rural, industrial and mining, residential land) forests, arable land, wetlands (Fan et al., 2014). Then, using the ISODATA unsupervised classification method, wetland land use is classified, and the classification results are processed to obtain wetland land use classification data (Wang et al., 2023).

4.2 Methods

This study is based on the 30 m RS images of Suzhou in 2013 and 2020, the vector data of the administrative area, the 30 m DEM, temperature, and precipitation data. The main research and analysis steps (Figure 6) are briefly described as follows:

1. Data collection and processing: Download the RS images required for land use type maps and wetland distribution maps from the geospatial data cloud, Data.geoatlas, and other platforms; preprocess the Landsat-8 images: including radiometric calibration, atmospheric correction, mosaic, and clipping.

2. RS image classification: Using ENVI software to perform ISODATA unsupervised classification on the image, and after distinguishing the characteristics of the ground features, merge the similar ground features. Then use ArcGIS to make a land use type map and a wetland distribution map.

3. Transfer the processed raster image to ArcGIS, extract the attribute elements of each land use type, and calculate its area.

4. Calculate the dynamic degree and transfer matrix of each land use type according to the formula.

5. Obtain the monthly average temperature and precipitation in 2013 and 2020 through the yearbook, make a comparison Table between the two periods, and analyze the factors affecting the change of the total wetland area.

6. Finally, conduct a comprehensive analysis, obtain the results, and make suggestions.

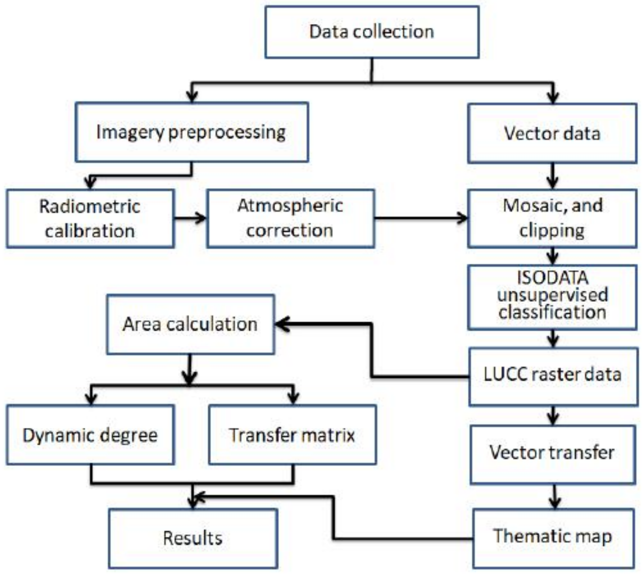


Fig.6 The Schema of The Study

4.3 ISODATA Unsupervised Classification

Unsupervised classification is also called cluster analysis, which means that no prior knowledge is applied to the classification process in advance but only based on the distribution law of the spectral characteristics of RS image features, using the characteristics of natural clustering to allow machines to learn and classify, which is based on the theory of clusters, and it is a method of pattern recognition to carry out cluster statistical analysis on images by computer. The main algorithms for unsupervised classification in the field of RS images are ISODATA and K-means. Among them, ISODATA classification is a repeated self-organizing data analysis technique that calculates the class mean value of the uniform distribution of data pixels, then uses the minimum distance algorithm to iteratively aggregate the pixels, recalculates the mean value in each iteration, and, according to the obtained new mean value, classifies the pixels again (Guo et al., 2017; Wang et al., 2023).

4.4 Land Use Dynamic Degree

The land use dynamic degree model can fully express the rate of land use change in a certain period of time in the study area (Zhang and Wang, 2023; Liang and Wang, 2023; Xie et al., 2023). According to different research objects, there are single land use dynamic degree and comprehensive land use dynamic degree, and the calculation formula is:

$$K = \left(\frac{H_b - H_a}{H_a}\right) \times \frac{1}{T} \times 100 \quad (1)$$

In the formula: K is the dynamic degree of a single land use; H_a, H_b are the area of the land use type before and after the study; T is the research period; the larger |k|, the greater the rate of change of a certain land use type in the study area.

$$L_c = \left[\frac{\sum_{i=1}^{n} \Delta LH_{i-j}}{2\sum_{i=1}^{n} LH_i}\right] \times \frac{1}{T} \times 100\% \quad (2)$$

In the formula: L_c is the dynamic degree of comprehensive land use; LH_is is the area of the i-th land use type in the previous period; ΔLH_{i-j} is the absolute value of the area of the i-th type of land converted into the j-th type of land use type; n is the number of land types (n=1, 2, 3...); T is the research period; the larger L_c, the faster the overall change rate of land use change in the study area.

4.5 Transfer Matrix

The transfer matrix method is used to quantitatively describe the system state and state transition. The transfer matrix can be used for quantitative analysis and in-depth understanding of the transfer area, transfer direction and supplementary sources of various species. It is mainly used to analyze the transfer rate and direction between different land use types in different periods, so as to analyze the internal correlation and change trend between land use types (Yu et al., 2018; Zhang and Wang, 2023; Liang and Wang, 2023; Xie et al., 2023). The transfer matrix formula is as follows:

$$S_{ij} = \begin{bmatrix} S_{11} & \cdots & S_{1n} \\ \vdots & \ddots & \vdots \\ S_{n1} & \cdots & S_{nn} \end{bmatrix} \quad (3)$$

In the formula: S represents the area of land use type transfer; n represents the classification number of land use types in the study area; i, j (i, j are integers of 1, 2, 3...n) represent the land use type before transfer and the area after the transfer of land use types; S_{ij} represents the number of land use types transferred from the i-th type of land use type to the j-th type of land use type.

V. ANALYSIS AND RESULTS

5.1 Changes in Land Use Types

By calculating the area of each land use type in Suzhou in 2013 and 2020, the proportion of land use type area and the dynamic analysis Table for the two-year period are obtained (Table 2). In addition, through ISODATA unsupervised classifications, four types of land use change maps were obtained for 2013 and 2020 (Figures 7 and 8) to present the characteristics of land use type change.

From the perspective of changes in land use types, the results show that over the past 7 years, the total wetland area in Suzhou has shown a downward trend, with a total change of -8.77%, while the construction land area has significantly increased, with a total change of 16.37%. Analysis shows that the main factors affecting the reduction of wetlands are the impact of human activities, especially such as building towns or scenic spots, cultivating arable land, and changing river channels, which have made the reduction of wetland area increasingly severe.

In addition, after calculating the area of four types of land use in Suzhou through ArcGIS, a single degree of land use dynamics was used to analyze land use changes, revealing the dynamic evolution process of land use in the study area in time and space. This can quantitatively describe the speed and severity of regional land use changes. Analysis of the dynamic degree of single land use in Suzhou from 2013 to 2020 (Table 2) shows that the absolute values of wetland and construction land dynamic degrees are relatively high, reaching 0.03 and 0.38, respectively. Over the past 7 years, except for construction land, other land use types have experienced varying degrees of reduction, especially the area of wetland types.

Table 2 Land Use Type Area Proportion/Dynamic Degree

Land-use type	2013 Area/k㎡	Rate%	2020年 Area/k㎡	Rate%	Variation	Land use dynamics degree
Water bodies	3337.41	39.05%	2583.63	30.28%	-8.77%	-0.03
Construction	521.81	6.11%	1917.69	22.48%	16.37%	0.38
Green land	2776.98	32.50%	2298.42	26.94%	-5.56%	-0.02

Arable	1909.6	22.35%	1732.23	20.30%	-2.04%	-0.01
Total	8545.8	100%	8531.97	100%	0.00%	0.00
Wetland area	3337.41	39.05%	2583.63	30.28%	-8.77%	-0.03
Area of Suzhou	8657.32	100%	8657.32	100%	0.00%	0

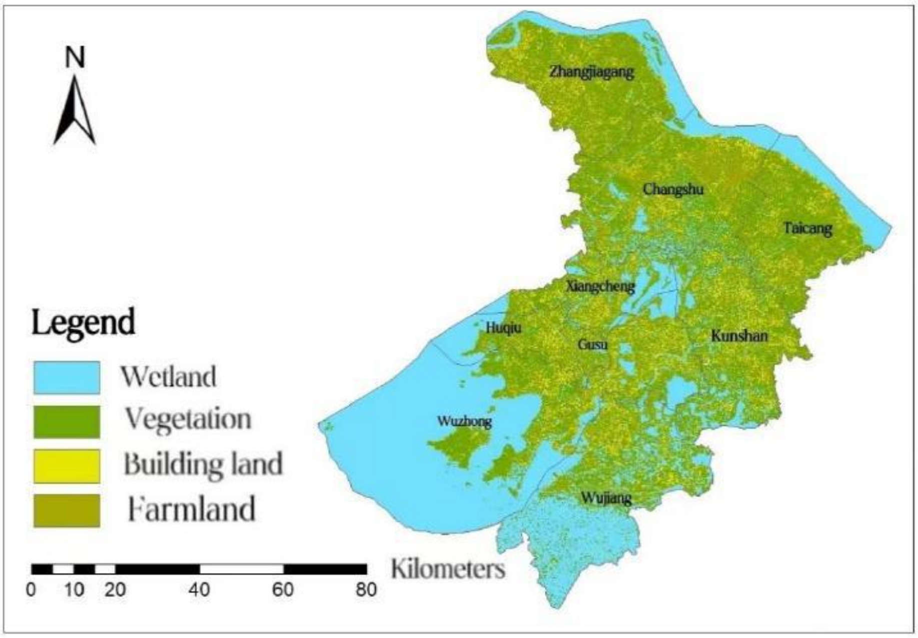


Fig.7 Land Use Types in 2013

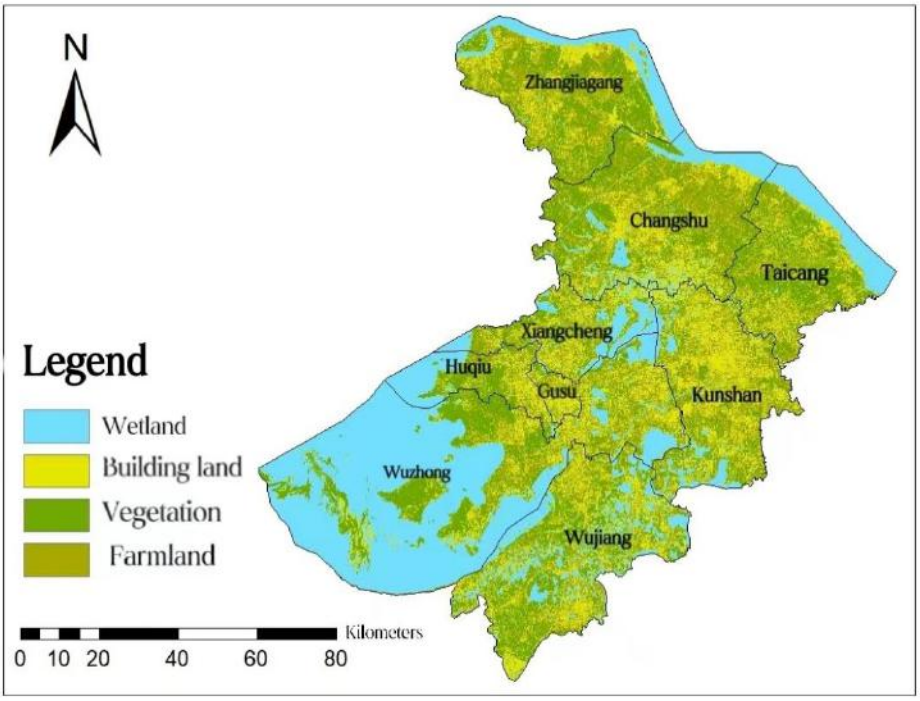


Fig.8 Land Use Types in 2020

The transfer matrix is used to present the magnitude and direction of changes between land types in different periods, so this method is used for specific analysis in this paper (Hu et al., 2023). Firstly, use ArcGIS to calculate the transfer situation between different categories in Suzhou in 2013 and 2020 (Table 3). From the perspective of the land use transfer matrix, it can be seen that (1) the conversion of construction land into green land has a high proportion; (2) the total area of construction land has significantly increased over the past 7 years; and (3) totally, the wetland area has decreased to a certain extent. Overall, with the rapid development of the social economy, the ecological environment has been damaged to varying degrees, and Suzhou wetlands show a decreasing trend in the land use transfer matrix (Li et al., 2023).

Table 3 Land Use Transfer Matrix /Unit：km²

Land types	Arable land	Construction land	Wetland	Green land	2020 year
Arable land	840.42	183.18	131.69	605.20	1760.50
Construction land	502.46	299.43	424.73	728.23	1954.85
Wetland	32.18	6.60	2491.04	60.80	2590.61
Green land	565.82	48.05	304.24	1414.34	2332.45
2013 year	1940.89	537.26	3351.70	2808.56	8638.41

5.2 Changes in Wetland Area

Based on the trend analysis of the total wetland area change, the RS classification results were combined with ArcGIS to create thematic maps and obtain the wetland distribution maps of Suzhou in 2013 and 2020 (Figures 9 and 10), which were processed and calculated using spatial data. The results show that from 2013 to 2020, the total area of wetlands showed an overall downward trend, with a total reduction of 753.78 km^2 a total change rate of -8.77% over 7 years. It can be seen from the comparison of the two thematic maps that the reduction of mudflat wetlands is the most severe, the reduction of mudflat wetlands in Wujiadng District is the most obvious, and the reduction of mudflat wetlands directly leads to the decline of natural wetland area. The overall area of lake wetlands shows a stable trend, mainly due to the increase in monthly average precipitation in Suzhou over the past 7 years. The large amount of precipitation has maintained the water storage area of the lake, thus keeping the lake wetland area stable. According to the statistical Table of land use types and areas, it can be seen that the construction land in this area has increased, thereby occupying the area of wetlands.

Based on the analysis of wetland land use evolution factors, urban construction has increased rapidly in the past seven years, and the main sources of construction land are Lake Mudflat wetlands and forestlands. The evolution of construction land and wetlands reflects the changing patterns of different land types in the process of economic development in Suzhou. In the early stages of urbanization and the transformation and development of related industries, most of them were achieved by converting natural wetlands. However, with the introduction of sustainable development concepts, this phenomenon has also improved (Zhu et al., 2017; Zhao et al., 2022; Yang et al., 2022).

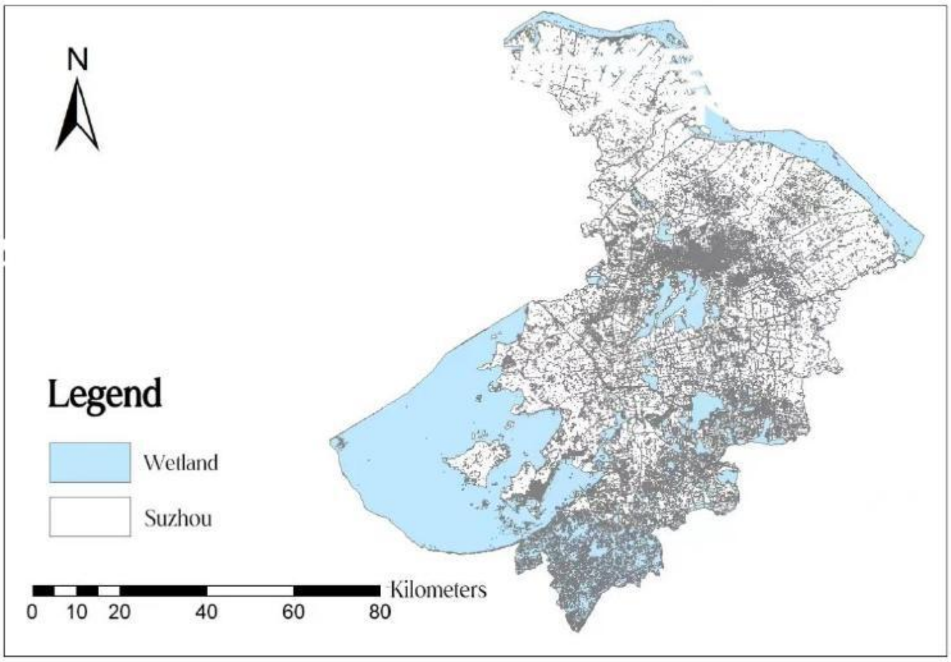


Fig.9 Distribution Map of Wetlands in Suzhou in 2013

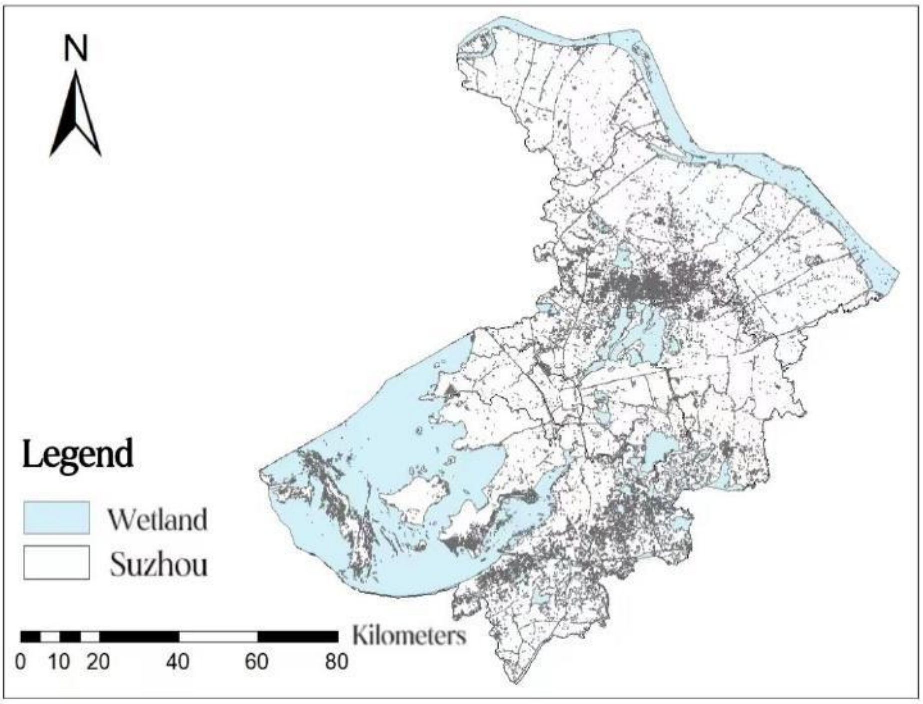


Fig.10 Distribution Map of Wetlands in Suzhou in 2020

5.3 Suggestions for Wetland Environmental Protection

Wetland protection is an important approach to achieve healthy and sustainable functions. The construction of wetland protection networks, the implementation of targeted protection methods, the construction of wetland special information databases, and phased evaluation of protection effectiveness are the crucial ways to protect wetlands. Based on the analysis results of this study and the evolution trend of wetland land use, several suggestions are proposed:

(1) Taking Wujiang District as an example, to deeply promote the high-quality development of sponge cities in various regions.

(2) Properly interfere with the reproduction of wetland species and maintain ecological balance.

(3) Utilizing the 3S system as a scientific method for monitoring the environment, continuously paying attention to the dynamics of the environment for a long time, in order to propose effective decision-making solutions in response to environmental changes.

(4) Design wetland tourism plans to help the public understand the wetland system and enhance their awareness of wetland protection.

(5) Regularly conduct large-scale water quality testing on wetlands to reduce water environmental pollution.

(6) Establish reasonable policies for the expansion of construction land to ensure the sustainability of wetlands.

VI. CONCLUSION

This study uses RS images of Suzhou in 2013 and 2020 as data sources and uses study methods and technical means such as ArcGIS, ENVI, land use dynamics, and a transfer matrix to analyze the dynamic degree in land use and wetland distribution in Suzhou over the past 7 years. Based on this, the dynamic degree and transfer matrix of various types of areas are analyzed. Finally, based on this, suggestions for optimizing and protecting the wetland environment in Suzhou and sustainable development are proposed.

Through land use evolution analysis, it is shown that the wetlands in Suzhou are affected by human activities, manifested in the accelerated urbanization process and the growth of construction land, resulting in a downward trend in the total area of wetlands. From the dynamic degree of land use, it can be seen that from 2013 to 2020, the growth rate of construction land was higher than that of other land uses, while wetlands, vegetation, and other land uses showed negative growth. From the land use transfer matrix, it can be seen that some areas of Suzhou have shown a decreasing trend in wetlands, while construction land has significantly increased, indicating that there is still a lack of coordinated development between Suzhou's economic development and wetland protection.

In summary, human production and life have a significant impact on changes in regional land use types. Faced with the increasing population and rapidly developing economic industries, how to balance the development and construction of artificial landscapes and natural wetland landscapes is a topic of continuous concern in the future. Therefore, establishing a reasonable wetland landscape planning system can stabilize regional economic development and ensure the balance of natural wetland ecosystems.

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Water Balance Analysis for Determination of Time Shift in Rice (*Oryza sativa* L.)

Based on Climate Projection Scenarios

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Abstract— *Rice production in East Java has decreased, which is related to climate change. Uncertain climate results in a shift in planting time. Climate projection scenarios are a solution to see future climatic conditions. One of the analyses used is the water balance. This study aims to study the water balance to determine the rice (Oryza sativa L.) planting time shift based on climate projection scenarios. The research was conducted from March to July 2022 in four districts of East Java. The materials used are average rainfall data and average temperature data for 2000-2020, climate projection data from the CNRM-CM5 and HadGEM2-ES models for 2025-2050, field capacity data, and permanent wilting point data. This study uses a selected sampling technique and the location is chosen as one of the rice production centers in East Java. This research uses exploratory descriptive analysis, statistical descriptive analysis, and the Thornthwaite and Mather method of water balance analysis. The research results show a shift in the planting time of rice plants in four districts in East Java for the years 2025-2050. Malang District experienced a change in the planting time of rice plants of 2 basics, Gresik District experienced a shift in the planting time of rice plants of 2-6 basics, Banyuwangi District experienced a change in planting time of 3-5 basics of rice and Pasuruan District experienced a shift in planting time of rice plants of 1-4 basics.*

Keywords*— *Water Balance, shifting planting time, rice plants, climate projection scenario.

I. INTRODUCTION

There are several parameters or climate factors that influence such as rainfall, air temperature, humidity, sunlight intensity, air pressure, and wind direction (Aditya et al., 2021). One important factor to support plant growth is water. Plants themselves have different water needs, including rice plants. Rice plants are plants that require a lot of water and are very sensitive to drought.

East Java is one of the provinces or regions in Indonesia which contributes to agricultural production with good results, one of which is rice. East Java is also one of the rice production centers. Based on BPS data for 2021, East Java is the largest producer by contributing 17.99% of rice production to total national production. However, over time, rice production has decreased due to several factors such as climate change. The impact of climate change that is clearly visible is the availability of water which is not enough to determine the right planting time. According to Apriyana et al., (2016) the impact of climate change resulted in a shift in planting time for rice plants ranging from 10-20 days from the normal planting time.

One of the efforts that can be made to reduce the impact of the shift in planting time is to develop a plan to see future climate conditions, namely with a climate projection scenario. Climate projections are the result of data processing from several modelling activities to determine future climate conditions based on the climate scenarios that will be used. The scenario used is an emission scenario with several levels such as low, medium to high (Surmaini and Faqih, 2016). The water balance is one of the analyzes that can be used for this climate projection scenario. The water balance is able to see the availability of water needed by plants and water balance such as shifts in planting time. This research is to study the water balance to determine shifts in the planting time of rice (Oryza sativa L.) based on climate projection scenarios.

II. MATERIALS AND METHODS

The research was conducted from March to July 2022 at the locations of Malang Regency, Pasuruan Regency, Gresik Regency and Banyuwangi Regency, East Java Province. The research was conducted in an exploratory descriptive manner. This research was conducted by identifying data, classifying secondary data based on research objectives, analyzing data and interpreting it. In this study the type of data used is secondary data which includes (1) BMKG rainfall and temperature data for 21 years, (2) climate projection scenario data from the CNRM-CM5 RCP 45 and RCP 85 models and the HadGEM2-ES RCP 45 and RCP models 85 for 26 years and (3) field capacity and permanent wilting point data.

The research location was determined using a purposive sampling method, namely choosing a location based on specific conditions (based on production centers, rainfall diversity and temperature). From this category, the research sample locations were Malang, Gresik, Banyuwangi and Pasuruan districts.

This study uses Explorative Descriptive Analysis and Statistical Descriptive Analysis. In addition, this research also uses water balance analysis, where the calculation of the water balance in this study uses the method developed by Thornthwaite and Mather (1957) with time per basis (10 days) with additional water surplus and deficit (loss).

III. RESULTS AND DISCUSSION

Rainfall and Temperature BMKG Data and Climate Projection Scenario Data

BMKG data results (observation) the highest rainfall in Malang Regency on the 3rd or January III, the CNRM RCP 45 model data results from the highest rainfall on the 36th or December III, the CNRM RCP 85 model data results from the highest rainfall on the 36th or December III, the results of the HadGEM RCP 45 model data have the highest rainfall on March 9 or III, the highest HadGEM RCP 85 model data results on March 9 or III. While the average temperature in Malang Regency from BMKG data (observations) is 23.6°C, the average temperature for CNRM RCP 45 data is 21.5°C, the average temperature for CNRM RCP 85 data is 21.7°C, the average temperature of the HadGEM RCP 45 data is 24.1°C and the average temperature of the HadGEM RCP 85 data is 24.3°C (Figure 1). This is in accordance with research conducted by Bagçaci et al., (2021) that the temperature results in the HadGEM2-ES model have a better rating when compared to the CNRM-CM5 model.

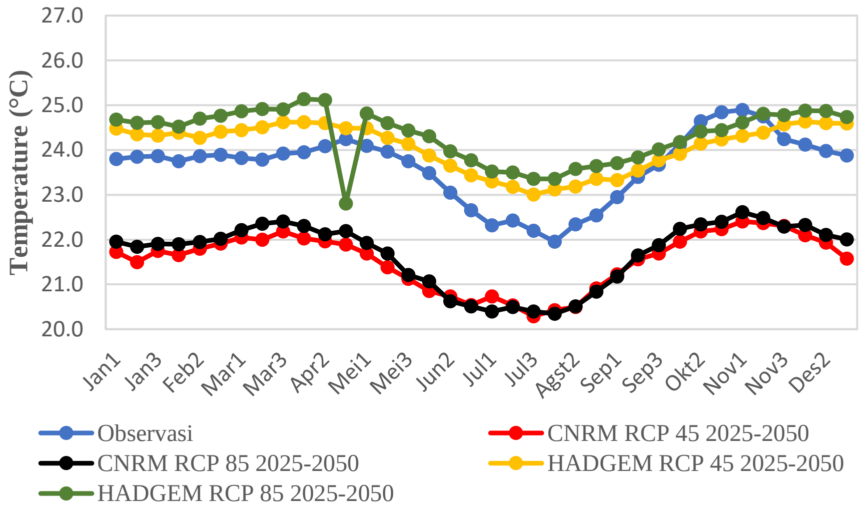

Fig.1. Average Temperature of Malang Regency

BMKG data results (observation) the highest rainfall in Gresik Regency on December 36 or III, the CNRM RCP 45 model data results the highest rainfall on December 36 or III, the CNRM RCP 85 model data results the highest rainfall on January 1 or I , the results of the HadGEM RCP 45 model data have the highest rainfall on the 3rd or January

III and the HadGEM RCP 85 model data results have the highest rainfall on the 4th or February 1st. Meanwhile, the average temperature in Gresik Regency from BMKG data (observation) is 28.1 °C, the average temperature of CNRM RCP 45 data is 27.8°C, the average temperature of CNRM RCP 85 data is 27.8°C, the average temperature of HadGEM RCP 45 data is 29.1°C and the average temperature -The average HadGEM RCP 85 data is 29.3°C (Figure 2). Thorndahl and Andersen (2021) stated that the temperature and rainfall results for RCP 85 would be more extreme when compared to RCP 45 due to an increase in greenhouse gases and no mitigation for reducing greenhouse gases.

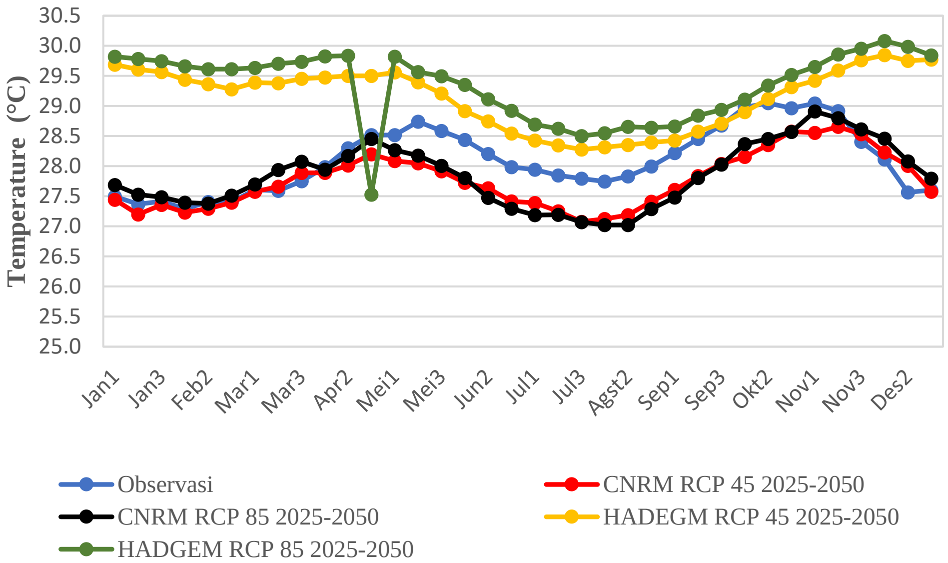

Fig.2. Average Temperature of Gresik Regency

BMKG data results (observation) the highest rainfall in Banyuwangi Regency on the 3rd or January III, the CNRM RCP 45 model data results the highest rainfall on the 11th or April II, the CNRM RCP 85 model data results the highest rainfall on the 8th or March II , the results of the HadGEM RCP 45 model data have the highest rainfall on the 12th or April III and the HadGEM RCP 85 model data results have the highest rainfall on the 14th or May II. While the average temperature in Banyuwangi Regency from BMKG data (observations) is 27.4°C, the average temperature for CNRM RCP 45 data is 24.0°C, the average temperature for CNRM RCP 85 data is 24.1°C, the average temperature of the HadGEM RCP 45 data is 27.3°C, the average temperature of the HadGEM RCP 85 data is 27.5°C (Figure 3). Based on research conducted by McSweeney et al., (2015) stated that the HadGEM2-ES model has good performance and is suitable for application in Southeast Asia.

BMKG data results (observation) the highest rainfall in Pasuruan Regency on the 3rd or January III, the CNRM RCP 45 model data results the highest rainfall on the 36th and 7th month or December III and March I, the CNRM RCP 85 model data results the highest rainfall on December 36 or III, the highest rainfall data for the HadGEM RCP 45 model is on March 8 or II and the highest rainfall for the HadGEM RCP 85 model data is on March 9 or III. While the average temperature in Pasuruan is BMKG data (observation) which is 21.8°C, the average temperature for CNRM RCP 45 data is 22.2°C, the average temperature for CNRM RCP 85 data is 22.4°C, the average temperature of the HadGEM RCP 45 data is 25.0°C and the average temperature of the HadGEM RCP 85 data is 25.2°C (Figure 4). Meng et al., (2017) stated that extreme shifts in rainfall and temperature can affect plant growth and yield.

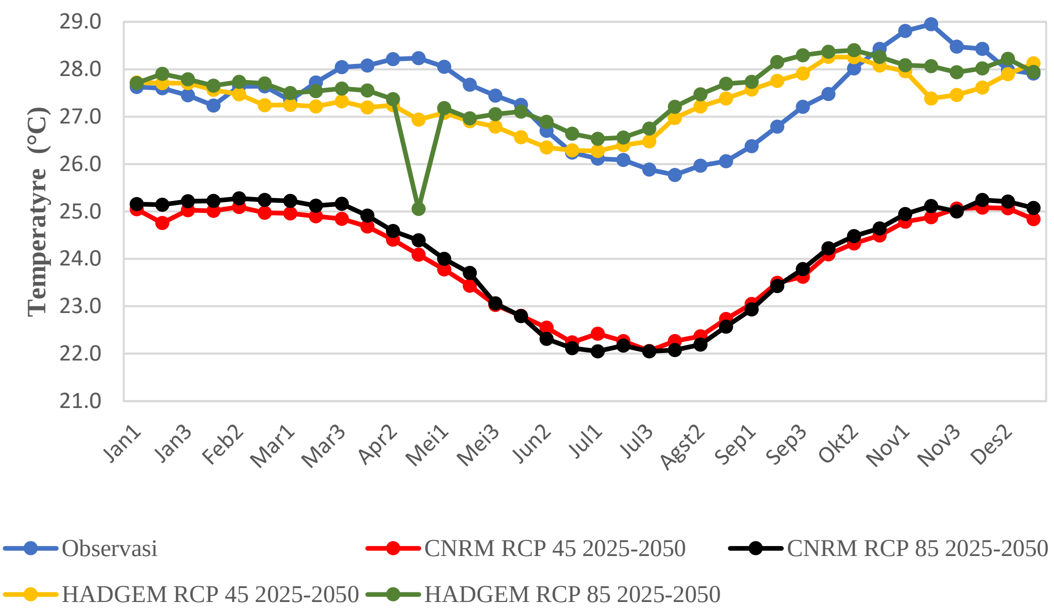

Fig.3. Average Temperature of Banyuwangi Regency

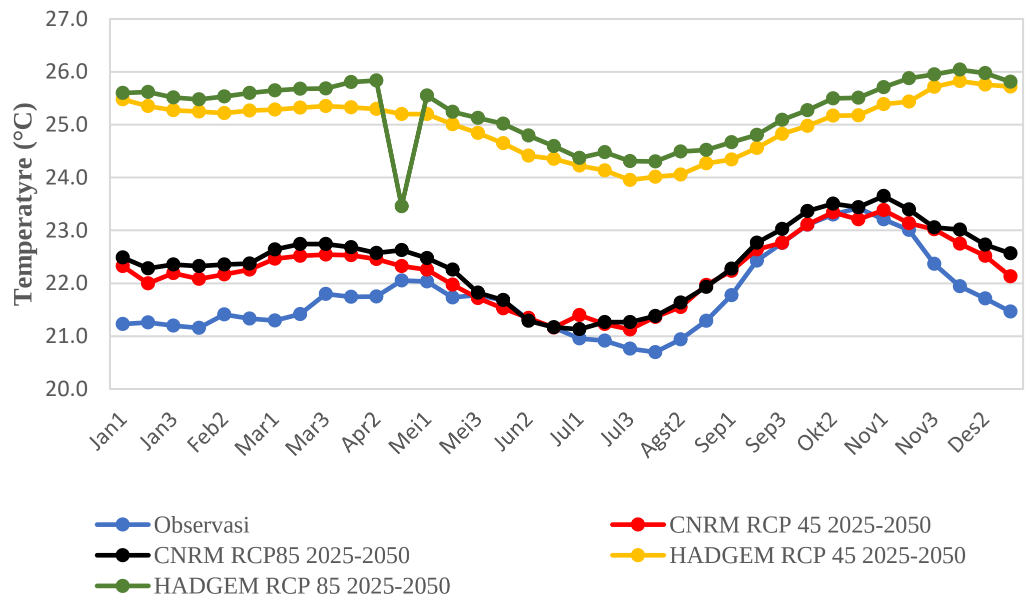

Fig.4. Average Temperature of Pasuruan Regency

BMKG Data Water Balance and Climate Projection Scenario Data

The results of the water balance in Malang Regency BMKG data (observation) experienced a surplus of 19 basis and a deficit of 16 basis (Figure 5), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 22 basis and a deficit of 13 basis (Figure 6), the result of the water balance of the data model CNRM RCP 85 experienced a surplus of 22 basisan and a deficit of 13 basisan (Figure 7), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 28 basisan and a deficit of 7 basisan (Figure 8) and the results of the water balance data of the HadGEM RCP 85 model experienced a surplus of 30 basisan and 6 basis deficit (Figure 9).

The results of the water balance in Gresik Regency BMKG data (observation) experienced a surplus of 20 basis and a deficit of 14 basis (Figure 10), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 13 basis and a deficit of 20 basis (Figure 11), the result of the water balance of model data CNRM RCP 85 experienced a surplus of 13 basis and a deficit of 22 basis (Figure 12), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 12 basis and a deficit of 24 basisan (Figure 13), the water balance result of the HadGEM RCP 85 model data experienced a surplus of 10 basisan and deficit 25 basisan (Figure 14).

The results of the water balance in Banyuwangi Regency BMKG data (observation) experienced a surplus of 9 basis and a deficit of 26 basis (Figure 15), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 12 basis and a deficit of 24 basis (Figure 16), the result of the water balance of the data model CNRM RCP 85 experienced a surplus of 12 basisan and a deficit of 23 basisan (Figure 17), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 23 basisan and a deficit of 11 basisan (Figure 18) and the water balance result of the HadGEM RCP 85 model data experienced a surplus of 23 basisan and deficit 11 basisan (Figure 19).

The results of the water balance in Pasuruan Regency BMKG data (observation) experienced a surplus of 27 basis and a deficit of 7 basis (Figure 20), the results of the water balance of the CNRM RCP model data 45 experienced a surplus of 21 basis and a deficit of 14 basis (Figure 21), the result of the water balance of model data CNRM RCP 85 experienced a surplus of 22 basisan and a deficit of 13 basisan (Figure 22), the water balance results of the HadGEM RCP 45 model data experienced a surplus of 34 basisan and a deficit of 2 basisan (Figure 23) and the water balance result of the HadGEM RCP 85 model data experienced a surplus of 29 basisan and a deficit of 6 basisan (Figure 24).

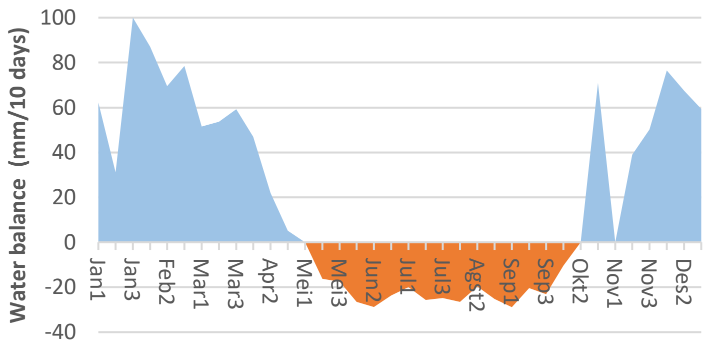

Fig. 5. Observation data water balance of Malang Regency

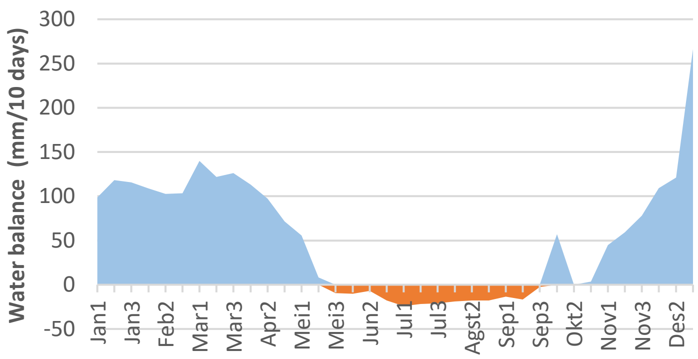

Fig. 6. Water balance data from the CNRM RCP 45 Model in Malang Regency

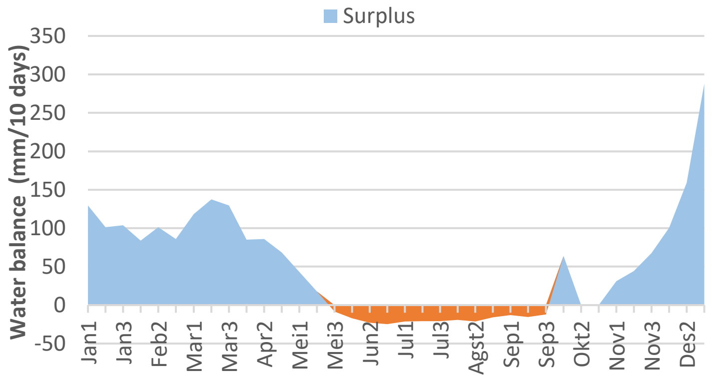

Fig. 7. Water balance of the CNRM RCP 85 Model data for Malang Regency

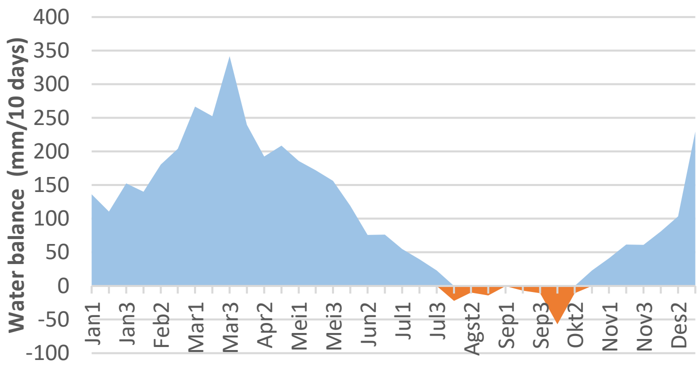

Fig. 8. Water balance of the HadGEM RCP 45 Model data for Malang Regency

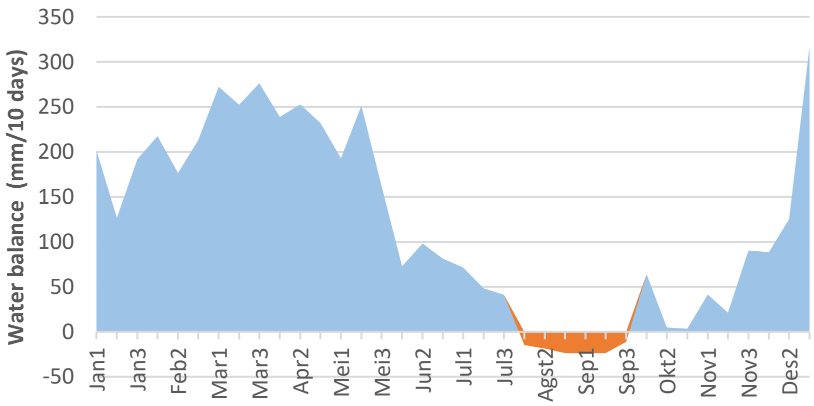

Fig. 9. Water balance of the HadGEM RCP 85 Model data for Malang Regency

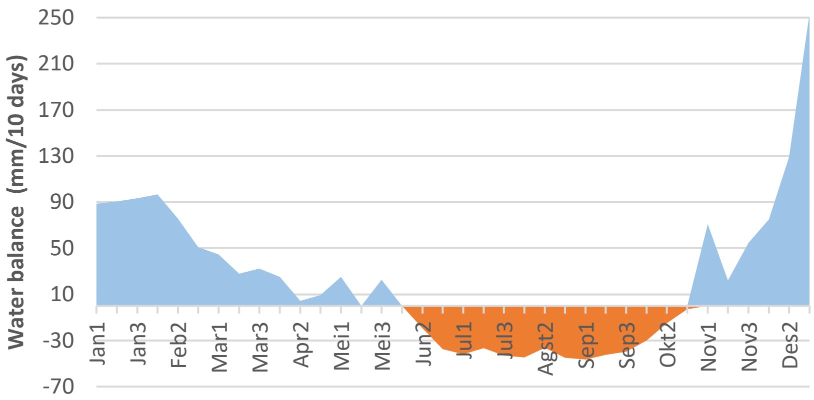

Fig. 10. Water balance Observation data of Gresik Regency

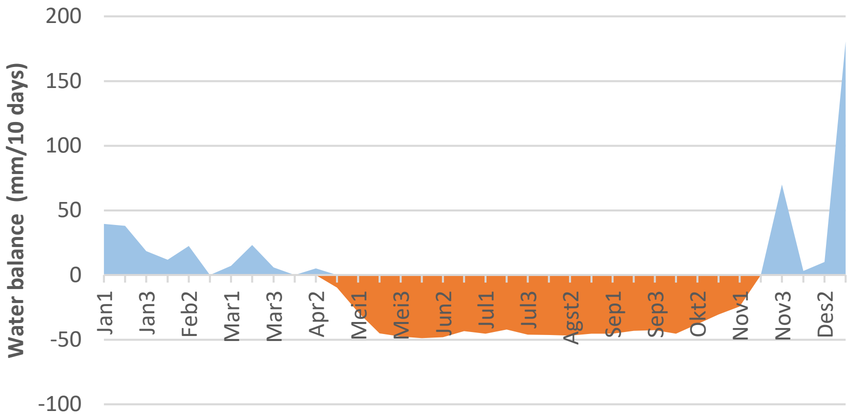

Fig. 11. Water balance data from the CNRM RCP Model 45 Gresik Regency

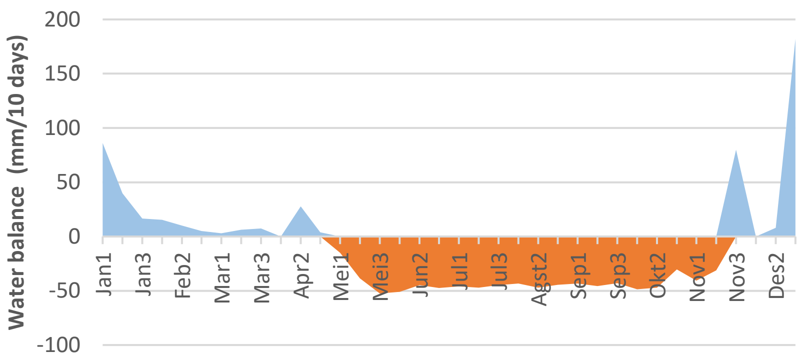

Fig. 12. Water balance data from the CNRM RCP 85 Model, Gresik Regency

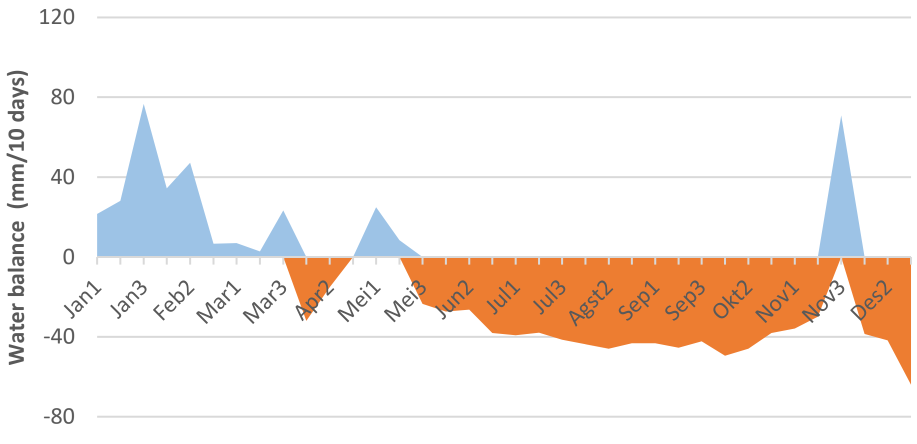

Fig. 13. Water balance data from the HadGem RCP 45 Model in Gresik Regency

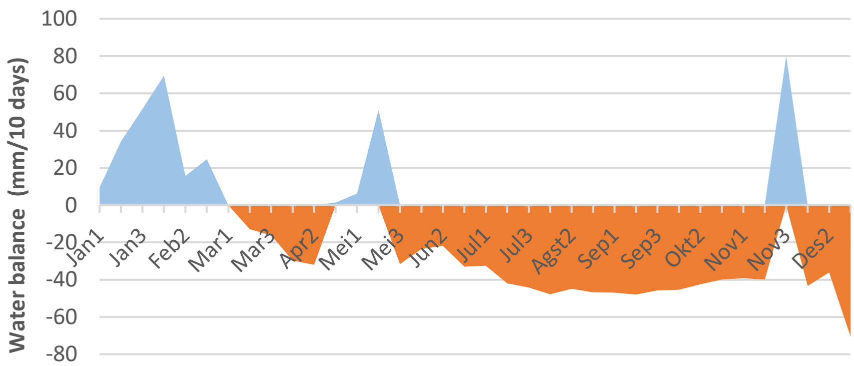

Fig. 14. Water balance data from HadGem RCP 85 Model Gresik Regency

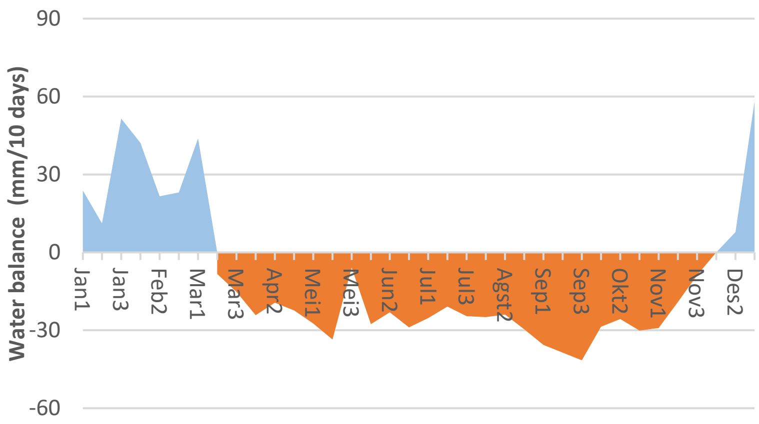

Fig. 15. Observation data water balance of Banyuwangi Regency

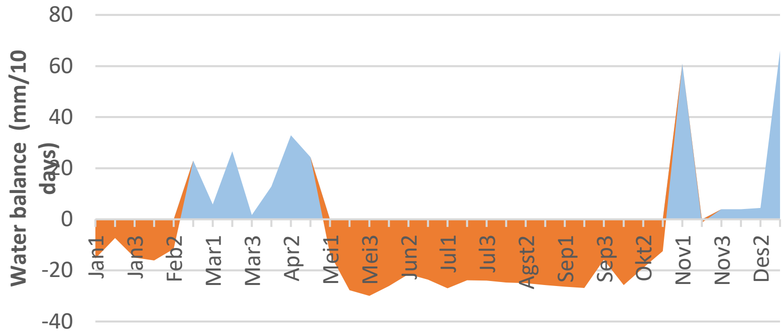

Fig. 16. Water balance data from the CNRM RCP 45 Model, Banyuwangi Regency

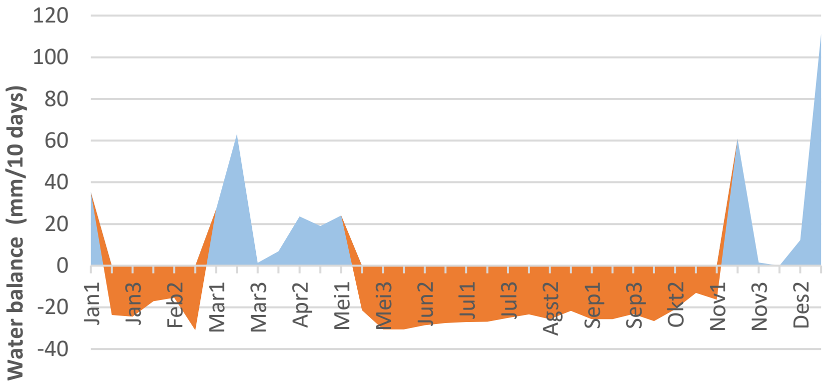

Fig. 17. Water balance data from the CNRM RCP 85 Model, Banywangi District

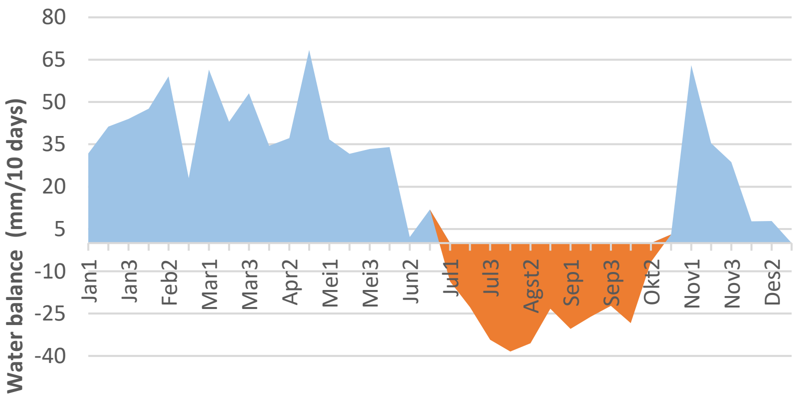

Fig. 18. Water balance data from the HadGEM RCP 45 Model of Banyuwangi Regency

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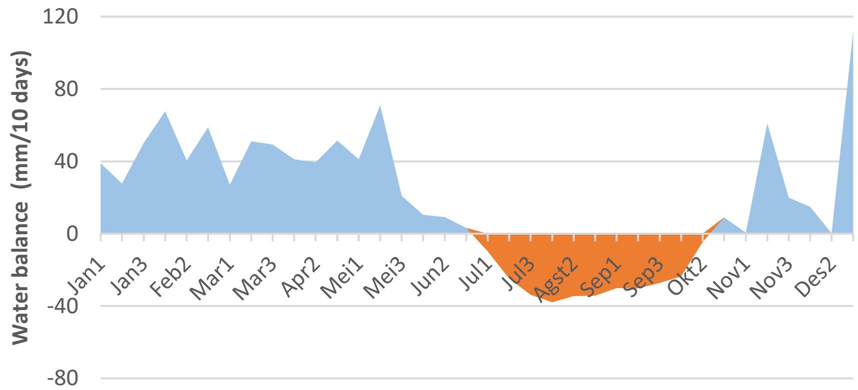

Fig. 19. Water balance data from the HadGEM RCP 85 Model of Banyuwangi Regency

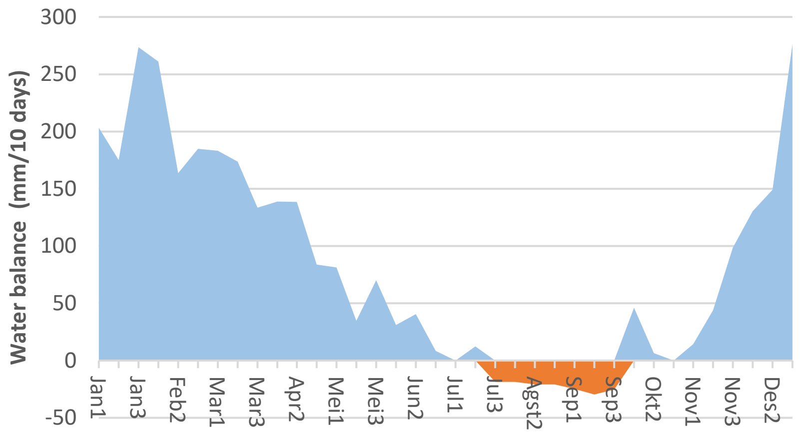

Fig. 20. Observation Data Water Balance Pasuruan District

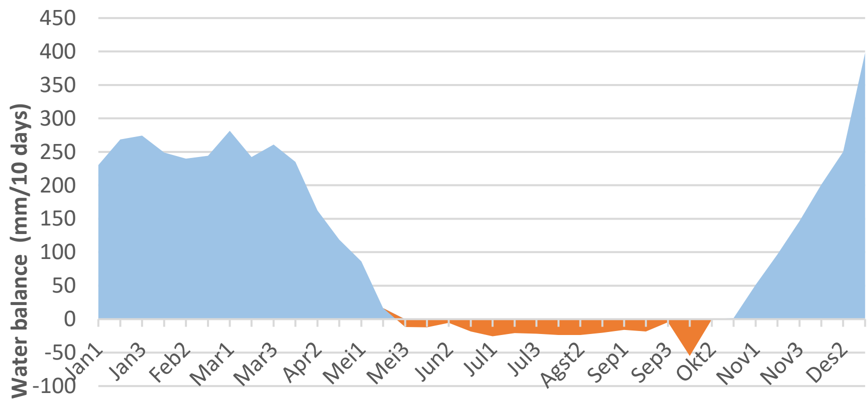

Fig. 21. Water balance data from the CNRM RCP 45 Model, Pasuruan Regency

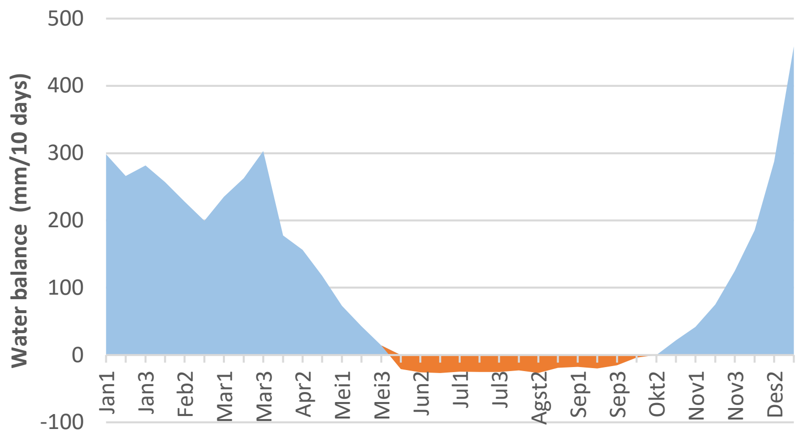

Fig. 22. Water balance data from the CNRM RCP 85 Model, Pasuruan Regency

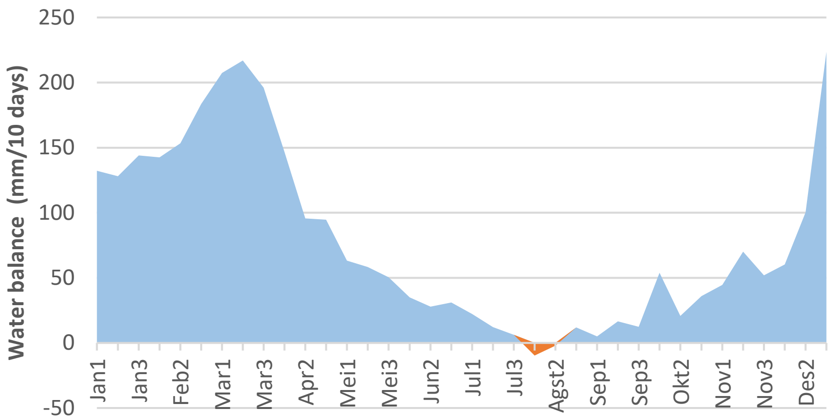

Fig. 23. Water balance data from the HadGEM RCP 45 Model, Pasuruan Regency

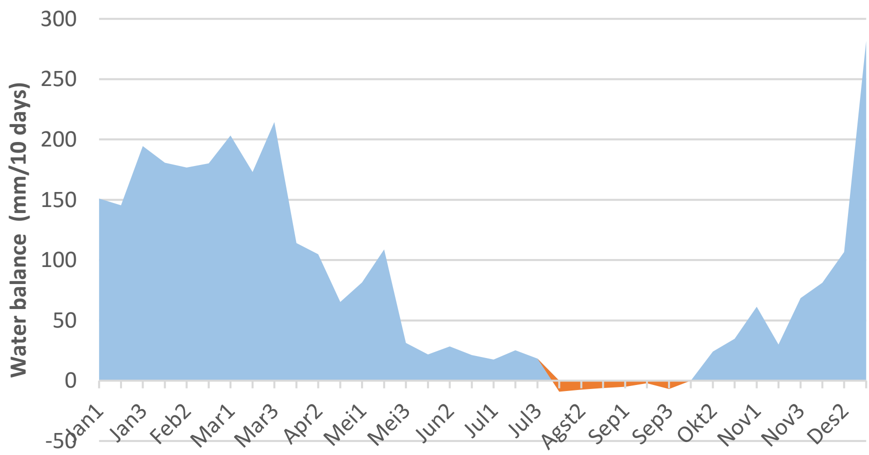

Fig. 24. Water balance data from the HadGEM RCP 85 Model, Pasuruan Regency

Shift in Rice Planting Time in Each Regency in East Java

rice planting time in Malang Regency BMKG data (observation) can be done in October III – February I, rice planting time CNRM RCP 45 model data can be done in October I – January II (experiencing a shift of 2 bases), rice planting time CNRM RCP model data 85 can be done October I – January II (experiencing a shift of 2 basis), rice planting time of the HadGEM RCP 45 model data can be done in October III – February I (no shift) and rice planting time of the HadGEM RCP 85 model data can be done October I – January II (experiencing a shift of 2 basis). According to Rahman (2018), climate change that occurs indirectly has an impact on water availability, when the total amount of rainfall decreases by around 10% and extreme temperature increases will result in more dry seasons.

Paddy planting time in Gresik Regency BMKG data (observation) can be done on November I – February II, rice planting time for CNRM RCP 45 model data can be done on November III – March I (experiencing a shift of 2 basis), rice planting time for CNRM RCP model data 85 can be done November III – March I (experiencing a shift of 2 basis), rice planting time of the HadGEM RCP 45 model data can be done January I – April II (experiencing a shift of 6 basis) and rice planting time of the HadGEM RCP 85 model data can be done January I – April II (experiencing a 6 basis shift). According to Mayasari and Anna (2020) stated that a shift in planting time that occurs, even if only for one basis (10 days), has the potential to reduce crop yields by up to 40%.

Paddy planting time in Banyuwangi Regency BMKG data (observation) can be done in December II – March III, rice planting time for CNRM RCP 45 model data can be done in November I – February II (experiencing a shift of 4 basis), rice planting time for CNRM RCP model data 85 can be done in November II – February III (experiencing a 3-difference shift), the HadGEM RCP 45 model rice planting season can be done in October III-February I (experiencing a 5-difference shift) and the HadGEM RCP 85 model paddy planting season can be done October III- February I (experiencing a shift of 5 basis). Rahman (2018) states that rainfall decreases over a long period of time and temperatures that increase by only 1% will result in a decrease in rice crop yields by 80%.

Paddy planting time in Pasuruan Regency BMKG data (observation) can be done on October I – January II, rice planting time for CNRM RCP 45 model data can be done on October III – February I (experiencing a shift of 2 basis), rice planting time for CNRM RCP model data 85 can be done in October III – February I (experiencing a shift of 2 basis), the rice planting time of the HadGEM RCP 45 model data can be done in August III – December I (experiencing a shift of 4 basis) and the rice planting time of the HadGEM RCP 85 model data can be done in October II – January III (experiencing a shift of 1 basis).

IV. CONCLUSION

1. Two model scenarios from the climate projection scenario that have been used and compared, namely the HadGem2-ES model and the CNRM-CM5 model, produced the right model and can be applied to Malang, Gresik and Banyuwangi districts, namely the HadGem2-ES model, while for the district The appropriate model for Pasuruan is the CNRM-CM5 model which refers to the results of rainfall, temperature and water balance.

2. There has been a shift in the timing of rice planting in four districts in East Java for 2025-2050 based on BMKG data (observation), CNRM-CM5 RCP 45 model data, CNRM-CM5 RCP 85 model data, HadGEM2-ES RCP 45 model data and HadGEM2-ES RCP 85 model data.

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Phosphorus release from a tropical estuary sediment: a laboratory study of Lake Maracaibo (Venezuela)

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Abstract— *The release of phosphorus (P) from bottom sediments is an important source of nutrient enrichment in many lakes. Reductive dissolution of P and iron (Fe) has been regarded as a mechanism responsible for the P mobilization in sediments. In this work, sedimentary P fluxes in the central portion of Lake Maracaibo were studied, considering the influences of dissolved oxygen, redox potential, pH, and Fe in the overlying water. Experiments were performed to laboratory scale in a batch system under anaerobic conditions in 1976, 1983, 1998 and 2009. For 2023, predictive models were applied. The estimated contribution of sediment to the P content in Lake Maracaibo ranged from 4.84 to 8.14x10^6 kgP/year, and the P release rate ranged from 1.66 to 10.30 mgP/m^2.d. On the last day of the experiment, the P concentration of the sediment was 0.251 mgP/g and of the sediments from the lake (hypolimnetic cone) was 0.253 mgP/g. Fe and the redox potential account for approximately 57% of the variability in total P in overlying water. The annual contribution of sedimentary P to the P content of the lake ranged from 11.13% in 1976 to 27.25% in 2023 (52.72% in 2009).*

Keywords— ***anaerobic conditions, eutrophication, inorganic nutrients, P loading, tropical estuary.***

I. INTRODUCTION

Sediments play a key role determining the concentrations of nutrients and pollutants in rivers, lakes, estuaries, and other shallow marine areas. The total phosphorus (TP) concentration is often much higher in sediments than in overlying water columns (Ladakis et al., 2006; Hylén et al., 2021). Consequently, changes in chemical species and their concentrations in sediments or disturbances in the fluxes into or out of water can have an enormous impact on the trophic status of water. Efforts to manage water quality in both fresh and marine water should consider sediment processes to be effective (Wetzel, 1981; Den Besten et al., 2003; Howarth & Martino, 2006; Dunn et al., 2015; Vo et al., 2021).

Quantifying the nutrient flux within a system can aid in determining the importance of controlling internal or external nutrient loading because it increases the concentration count of soluble forms that can be released into the overlying water column in addition to increasing the total nutrient content of the sediment (Reddy et al., 1998). The management of external nutrient inputs to eutrophic systems can be confounded due to a persistent pool of P in lake sediments (Giles et al., 2016). Although reduction of external phosphorus input can be achieved, the release of internal phosphorus from sediments can be the major contributor for the lake eutrophication processes (Ma et al., 2019; Cavalcante et al., 2021). Nutrient enrichment of estuarine waters can result in accelerated accumulation of organic matter in sediments, thus leading to a nutrient flux from the sediment to the water column (Malecki et al., 2004).

The study of the behavior of phosphorus in the Lake Maracaibo system, particularly the transfer of phosphorus across the water-sediment interface, provides additional valuable data for implementing measures to mitigate the acceleration of the eutrophication process in this natural reservoir (Parra-Pardi, 1979; Rivas, 1983). Knowledge concerning the phosphorus cycles and transformations is essential to the ecological understanding of estuarine systems (González, 1994). The Lake Maracaibo is a tropical hypereutrophic estuary located in the state of Zulia in North-Western Venezuela. The Maracaibo Basin, located on the northern front of South America, is the most important oil reserve in South America and one of the largest oil reserves in the world. Between 1914 and 1995, the total amount of oil extracted from the basin was 33,000 million barrels (5,238x10^6 m^3). Most of this oil originates from the bottom of the lake, which is the largest lake in South America and the 17th largest lake in the world (Rodríguez, 1999). The cretaceous source rocks in this petroleum system are responsible for the bulk of the hydrocarbon reserves in the Maracaibo Basin (Goddard & Talukdar, 2002). Accelerated urban expansion (due to the presence of a major petrochemical industrial park), sewage waters, and agricultural activities have exacerbated the deterioration of the basin. Moreover, the continuing development of the lakeshores has reduced the water quality over the years (Parra-Pardi, 1979). Some 500 companies, including chemical refineries and coal mining operations, currently dump wastewater into the lake. Redfield (1958) was the first to note that the hydrobiological conditions of the Maracaibo basin are highly favorable to the processes that start the accumulation of oil-producing materials. Pesticide-loaded runoff from farms and oil leakage from pipelines dynamited frequently by guerrilla rebels in Colombia also flow into the basin through its tributaries, particularly the Catatumbo River. Most of the pollution, however, comes from raw sewage from the approximately 5 million inhabitants surrounding the basin.

The DISCA (División de Investigaciones sobre Contaminación Ambiental) conducted a series of survey cruises to monitor the water quality and biological characteristics of the lake between 1974 and 1978; they found a close relationship between the conformation of the saline hypolimnetic cone and the anaerobic zone. It was shown that the conformation of the cone, due to the presence of a saline gradient, produces a reduction in water movement, resulting in a drastic decrease in dissolved oxygen between 15 and 17 m depth. During the rainy season, when the hypolimnetic cone diminishes, the influx of fresh water, originating mainly from the Catatumbo River, dilutes the anaerobic water containing organic matter and nutrients. This diluted water then rises and subsequently mixes with water from the epilimnion, thus diminishing the dissolved oxygen. Lake Maracaibo was selected from a group of shallow lakes surrounded by highly populated areas that are vulnerable to eutrophication.

Eutrophication of this lake causes massive growth of blue-green algae at certain times of the year (April-June), presenting an environmental problem (Rodríguez, 2001; Troncone et al., 2006b). This process occurs as a result of the elevated content of nutrients in the water caused by agricultural and industrial activities and the unloading of residual waters (Parra-Pardi, 1983). The continuous accumulation of phosphorus at the bottom of the lake throughout the years has created a phosphorus source that will continue to release phosphorus into the lake for a long time (Rivas, 1983). Kiage & Walker (2009) showed that the main causes of the proliferation of floating vegetation were rainfall anomalies in the preceding months (higher local rainfall would produce more runoff into the lake from approximately 30 rivers) and population growth in the major cities surrounding Maracaibo: Cabimas and Ciudad Ojeda. In a complex ecosystem, such as Lake Maracaibo, the use of models allows for the exploration of possible outcomes of various management options (*e.g.*, closing the shipping channel and/or reducing anthropogenic nutrient inputs) without the risk of inadvertently causing an undesirable change in the ecosystem (Medley, 2001). The study of phosphorus transfer across the water-sediment interface in the Lake Maracaibo system, particularly internal phosphorus loading, provides additional valuable data for implementing measures to mitigate the acceleration of the process of eutrophication in tropical reservoirs. There is currently little information regarding the role of sediments in the eutrophication processes in tropical water bodies.

The main objective of this work was to estimate, in a laboratory under anaerobic conditions (for 1976, 1983, 1998 and 2009), and through predictive regressions (for 2023), the phosphorus flow across the water-sediment interface and the rate of P accumulation in sediments. To accomplish this objective, this study determined: i) P flux from sediments, ii) Influence of Fe on P release from sediments, and iii) The annual internal load of P from the sediment to the overlying water column of the lake. The experiments were designed to simulate conditions similar to those in the hypolimnetic cone (the area with highest nutrient accumulation), where samples of sediments were taken. During the last years it has not been possible to continue studying in the Lake Maracaibo system due to the difficult situation of the country. Thus, the importance of this work lies in documenting the information about the phosphorus mobility in sediments of a tropical hypereutrophic estuary under the influence of dissolved oxygen concentration, serving as background for the future study of water-sediment interactions in coastal ecosystems, coupled with the impossibility of being able to carry out similar studies in the short and medium term considering the current economic situation in Venezuela and the dismantling of the country's research centers.

II. MATERIALS AND METHODS

2.1. Study area

Lake Maracaibo is a large, tropical, warm (30-32°C), hypereutrophic, oil-polluted aquatic system (zmax= 34 m, zmean= 28 m, V= 245x10^9 m^3, A= 12,958 km^2). It is the largest lake in South America and the center of oil shipping activities in western Venezuela. Although Lake Maracaibo is partially a mixed estuary, the system as a whole includes almost all categories of water bodies: marine (Gulf of Venezuela), estuarine (Strait of Maracaibo and Bay of El Tablazo), fresh water lake (Lake Maracaibo), and flowing streams (tributary rivers). This tropical lake is located between 70°30’ and 73°24’ W longitude and between 9°00’ and 10°30’ N latitude (Parra-Pardi, 1979) (Fig. 1).

Lake Maracaibo shows variable salinity, ranging from 5.0 to 8.0 pus, depending on the influx of seasonally fluctuating rainwater from land drainage, and seawater. Outflow from the lake to the Bay of El Tablazo and to the Gulf of Venezuela predominates during the wet season and usually reverses during the dry season (Gadner et al., 1998). The predominant physical feature of the lake water is the formation of a very consistent hypolimnetic cone, with its base in the central area of the bottom of the lake and its apex in a variable point near the center of the lake, at 5 to 15 m. The salinity of the hypolimnetic cone is higher than that of the epilimnion due to the intrusion of diluted seawater (generally 6 to 10%, although the upper

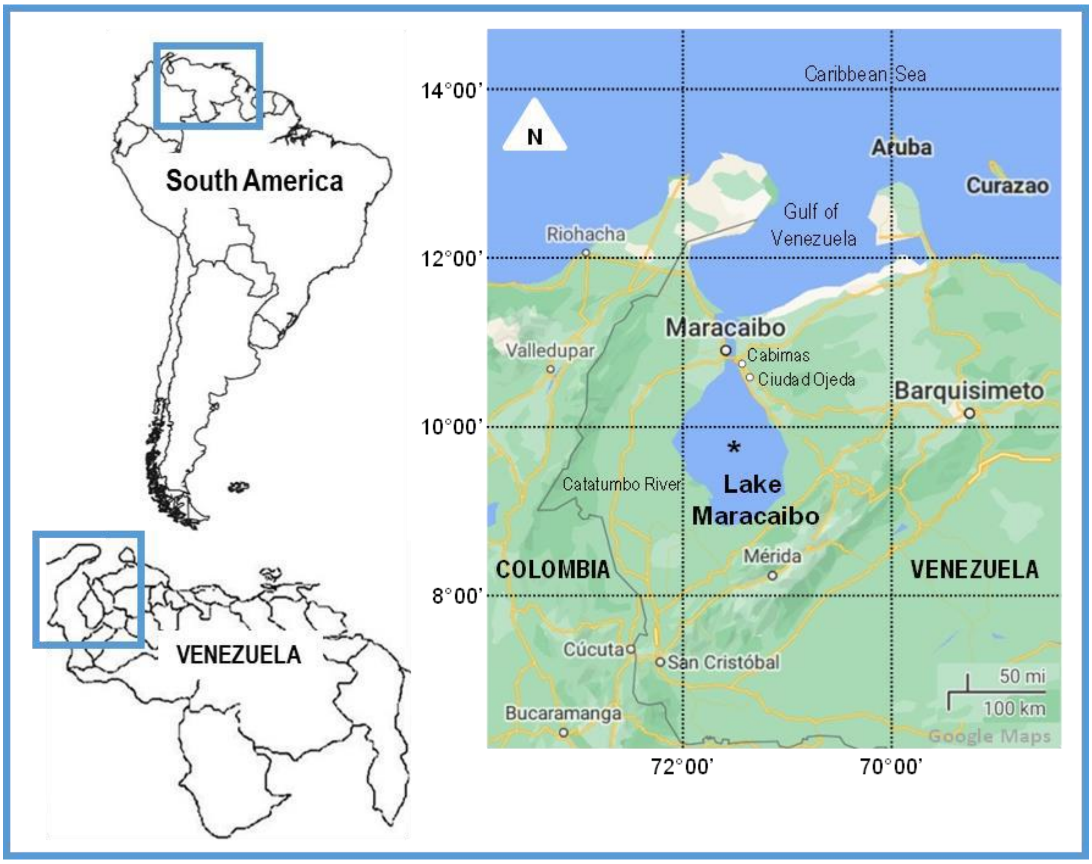

Fig. 1: Location of the Sampling Site (*) from Lake Maracaibo (Venezuela)

limit can be exceeded), which upon arrival at the deeper areas of the lake, is incorporated into the hypolimnion and slowly dispersed toward the epilimnion through the process of erosion (Parra-Pardi, 1983). Seawater enters Lake Maracaibo through an augmented natural connection to the Gulf of Venezuela, which allows an influx of seawater and results in an almost perennial salt stratification within the lake (Laval et al., 2005). The dynamics of this enclosed system are rather unique, with water bodies interacting among themselves and responding to external forces (Antoranz et al., 2001).

2.2. Sampling

Sediment samples from the hypolimnetic cone described above, taken from the central area of the lake (71°31’41” W-09°51’17” N), were used (Fig. 1). Sediment sampling took place during research cruises in 1976, 1983, 1998, and 2009. Bottom sediment and overlying water samples were collected using an Ekman dredge and a water sampling system coupled with a peristaltic pump, respectively. The samples obtained were kept frozen until retrieval at onshore laboratories. Physical and chemical characteristics, including temperature, dissolved oxygen concentrations, electric conductivity, salinity, and pH, were measured using a Hydrolab Surveyor II.

2.3. Experimental system and chemical analysis

To prepare the batch system, sediments were placed into two bottles that were used as reactors. Additional samples of water and sediment were tested for physical and chemical characteristics. Water and sediments were analyzed before and after the experiment. Water from Lake Maracaibo was carefully siphoned on top, avoiding disturbance of the sediment. In each bottle, a bubbler was installed above the sediment. Bottles were aerated by purging argon gas to create anaerobic conditions.

All incubations were performed in darkness at 25°C. Every two days over the course of three months, overlying water samples were analyzed for dissolved oxygen, pH, redox potential (electrometrically), orthophosphate (ion chromatography using Dionex 200i-sp equipment), and total phosphorus (APHA et al., 2017). Dissolved oxygen was measured using a YSI model 58 O_2 meter (Yellow Springs Instruments Company) equipped with a YSI model 5730 stirring electrode by means of the USEPA Method 360.19 (USEPA, 1979). pH values were attained using a Fisher Scientific (Pittsburgh, PA) 640A pH meter, and the redox potential was measured using a Metrohm 678 EP/Kf Processor with a 6.0402.100 platinum Metrohm electrode. Total iron concentrations were analyzed in 5 ml overlying water samples treated with 2 ml of concentrated nitric acid and digested for 4 hours at 130°C in a Parr-type bomb. The final dissolution was analyzed with a flame atomic absorption spectrometer Perkin Elmer 3100 instrument. Three replicates were performed for each analysis.

For the sampling performed in 2009, iron concentrations were analyzed using 3 ml of overlying water and 2 ml of concentrated nitric acid that were heated for 4 hours at 101±2°C. The samples were diluted to a final volume of 40 ml and centrifuged and analyzed using an inductively coupled plasma emission spectrometry (ICP-AES) Thermo Scientific series 6000. ICP-AES and UV-Vis techniques were compared and present a satisfactory linearity of 0.0085 (Torres, 2012). TP was analyzed using a Shimadzu UV-1800 Spectrophotometer. Sediment samples were analyzed before and after the experiment as follows: i) Total phosphorus: 2.5 g of sediment were ignited for 2 hours in a furnace at 550°C, allowed to cool for 1 hour, diluted with 10 ml of 1 N HCl, and boiled for 1 hour. The sample was then filtered and completed to 10 ml with distilled water to be analyzed as orthophosphate using the standard ascorbic acid method (APHA et al., 2017); ii) Orthophosphate: 2.5 g of sediment were extracted with 100 ml of the acid mixture H_2SO_4-HCl 1 N, stirred for 2 hours, filtered, and analyzed by the standard ascorbic acid method (APHA et al., 2017). The sediment water content (porosity) was determined based on the weight loss upon drying at 105°C; and iii) Iron determination: 0.1 g of sediment sample was digested with 5 ml of concentrated nitric acid and 5 ml of deionized water in a Parr-type bomb at 110°C for 4 hours. The final solution was analyzed by flame atomic absorption spectrometry using the same instrument as above. Three replicates were performed for each analysis.

For the sampling performed in 2009, 2.5 g of lyophilized sediments was heated at 550°C for 2 hours. Samples were cooled, added to 10 ml of 1 M HNO_3, and heated to the boiling point for 1 hour. The samples were diluted to a final volume of 50 ml with deionized water. Phosphorus was determined using a Shimadzu UV-1800 Spectrophotometer. Iron was analyzed using the ICP-AES Thermo Scientific series 6000. The results are expressed in dry weight (DW).

2.4. Statistical analysis

Phosphorus flux rates were determined by measuring changes in the water column concentrations of sediments over time. Using least-square linear fits to the data, fluxes ($mgP/m^2.d$) were estimated by multiplying the slope of a plot of concentrations versus time (dC/dt) by the ratio of the overlying water volume (V) to the reactor area (S). Statistical analysis was performed using SPSS 22.0 analysis software. The means and standard deviations of each parameter used for sediment characterization and the nutrient fluxes were calculated using Microsoft Excel 7.0. One-way ANOVAs were used to determine the significant differences ($P<0.05$) in phosphorus fluxes under both aerobic and anaerobic conditions. Multiple linear regression analyses were performed using TP as the dependent variable. The independent variables used were pH, total iron (TFe) and redox potential.

In 2023 it was not possible to carry out the laboratory experiments due to the economic crisis that Venezuela is going through; however, predictive estimates were made through regression models according to Zamyadi et al. (2007) and Lathrop et al. (2019), in order to know the TP contribution from sediments at the present time.

III. RESULTS AND DISCUSSION

3.1. Phosphorus concentrations in Lake Maracaibo

The characteristics of the sediments and water overlying the sediment from Lake Maracaibo before the experiments are shown in Tables 1 and 2, respectively. The TP values of the sediment samples ranged from 1.0 to 2.6 mg/g. According to Carignan (1985), when the TP levels of sediment range from 0.325 to 0.771 mg/g, a lake is considered eutrophic. Therefore, Lake Maracaibo can be considered eutrophic. It is particularly noteworthy that the concentrations of TP and TFe in the sediments are higher in samples collected in 2009 than in samples collected earlier, which is most likely due to sediment saturation (Table 1) and clearly indicates the progressive eutrophication of the lake over the course of these years. This trend is also shown in the overlying water (Table 2). Studies describing the typical TP values found in water samples from various limnetic ecosystems show that such concentrations do not exceed 0.01-0.04 mgP/l (Snoeying & Jenkins, 1990). The TP values found in Lake Maracaibo lie far outside of this range, with a total average phosphorus concentration of between 0.28 and 0.52 mgP/l.

3.2. Phosphorus in overlying water in batch system

Fig. 2 shows the evolution of the TP transfer from sediment to water in the years 1976, 1983, 1998, and 2009. All of the TP concentrations increase until approximately day 20. The experiments in the years 1976, 1983, and 2009 produced uniform results, with growth until day 20, followed by stabilization. This stabilization is presumed to be the result of reaching an equilibrium between sediment and water. The data recorded in 1983 followed this same trend, although there were instances of twofold and threefold increase between days 50 and 70. The combined effects of rapid adsorption and desorption of P may cause a sharp gradient in soluble P to be sustained in the sediment-water interface of aquatic systems, which could result in a significant flux of P to the water column. This occurrence was observed in the instances of greater increases, particularly in 2009 and after day 50 in 1983.

Table 1: Average Composition of the Lake Maracaibo Sediments at the Beginning of the Experiments

Parameter	1976	1983	1998	2009
Dry matter (%)	25.50±2.25	43.80±3.20	25.80±1.70	ND
Total-P (mg/g DW)	1.00±0.05	1.19±0.04	1.21±0.01	2.63±0.03
Total-N (mgN/g DW)	8.70±0.52	14.50±0.80	5.47±0.25	2.68±0.02
Ammonium (mgN/g DW)	0.10±0.05	0.19±0.01	0.03±0.00	0.02±0.00
Total-Fe (mgFe/g DW)	23.50±0.40	ND	36.53±1.10	51.49±0.39
n	5	5	5	3

ND: non-determined.

Table 2: Average Characteristics of Overlying Water in Lake Maracaibo

Parameter	1976	1983	1998	2009
pH	7.64±0.15	8.30±0.10	6.84±0.07	6.80±0.02
Salinity (pus)	5.66±1.15	5.09±0.40	7.8±0.30	8.90±0.03
Total-P (mgP/l)	0.28±0.01	0.43±0.02	0.47±0.02	0.52±0.02
Total-N (mgN/l)	ND	2.40±0.02	1.46±0.03	ND
Orthophosphate (mgP/l)	0.19±0.02	0.15±0.06	0.34±0.01	0.50±0.02
Ammonium (mgN/l)	0.35±0.02	1.68±0.06	0.68±0.00	0.10±0.01
Dissolved oxygen (mg/l)	0.01±0.00	0.01±0.00	0.02±0.00	0.00±0.00

Chlorophyll (µg/l)	2.00±0.03	2.40±1.10	0.76±0.05	ND
n	3	3	3	3

ND: non-determined.

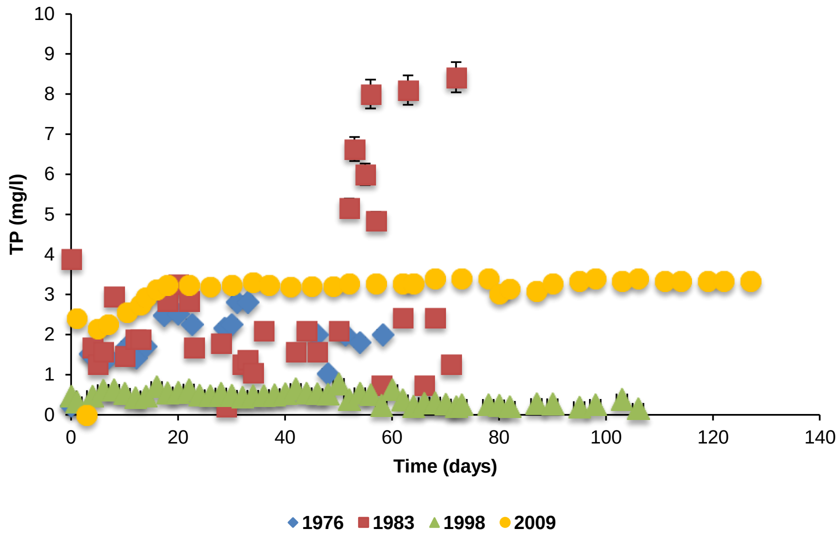

Fig. 2: Temporal Sedimentary Total Phosphorus (TP) Release in the Batch System

3.3. pH in overlying water

The greatest quantity of phosphorus release was 0.655 mgP/l, which was observed at pH 8 (Fig. 3). The phosphorus release at pH 8 was four times higher than that at pH 5.8, which was 0.159 mgP/l. The operational scheme of P fractionation includes P reactive to metal oxides; NaOH-extractable P (Fe/Al-P, P bound to Al, Fe and Mn oxides and hydroxides); reductant soluble reactive P (BD-P), which represents the redox-sensitive P fraction and mainly included P bound to Fe-hydroxides and Mn compounds; calcium-bound P; and HCl-extractable P (Ca-P, P associated with Ca). High pH promotes the release of NaOH-P and BD-P, and low pH promotes the release of HCl-P (Shengrui et al., 2006; Xiangcan et al., 2006).

The rate of P release in these laboratory experiments increased as pH increased from 5.7 to 8. In sediments from Lake Maracaibo, the contribution of NaOH-P was 18.77%, that of BD-P was 35.67%, and that of HCl-P was 34.16% (Torres 2012). At alkaline pH, NaOH-P and BD-P can be easily released in sediments and were the main P release fractions. NaOH-P and BD-P contributed over

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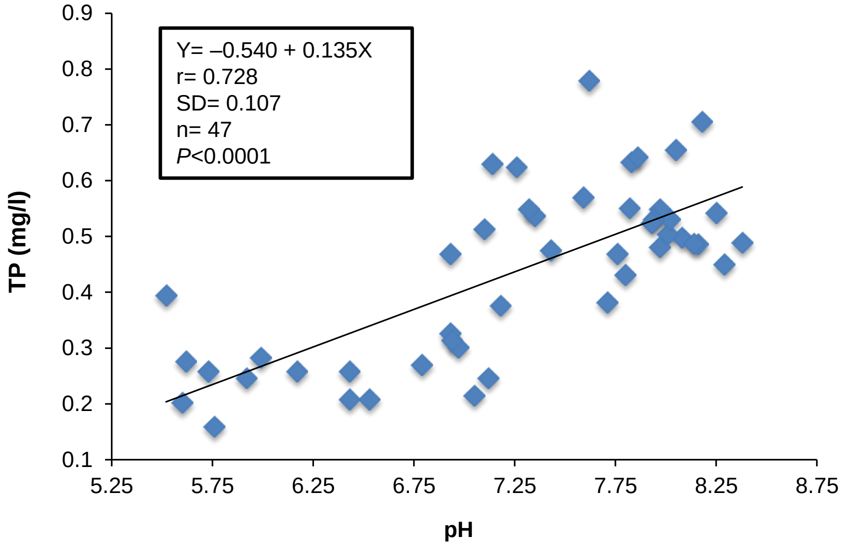

Fig. 3: Correlation between Total Phosphorus (TP) and pH in the Batch System

50% of the total P released from the sediments to the overlying water. This is consistent with the results found by Torres (2012) who showed that Al, Fe, Mn and Ca were 51.428, 66.871, 2.991 and 4.880 mg/kg, respectively, meaning that Al and Fe (NaOH-P and BD-P) were higher than Ca (HCl-P). A linear regression analysis indicated that pH data positively correlated with TP (Fig. 3):

$$Y = -0.540 + 0.135X,\ r = 0.728,\ n = 47,\ P<0.0001 \quad (1)$$

3.4. Redox conditions in overlying water

Redox potential had a critical influence on the release of phosphorus. A potential interval of –80.3 to 82.0 mV was found. In general, the release rates were higher under reductive redox conditions (–80 mV) and high pH values. Under anoxic conditions, Fe(III) is reduced to Fe(II). Phosphorus has a strong affinity to iron oxide, aluminum, and manganese (Roy et al., 2012). The reduction and oxidation (redox) of these metals regulate the dynamics of phosphorus in sediments. The mechanisms of phosphorus mobilization are explained by the reductions of insoluble metal oxides, such as Fe(III) to soluble Fe(II) in sediments or water (Chistophoridis & Fytianos, 2005). Linear regression analysis indicated that redox potential was negatively correlated with TP:

$$Y = 0.397 - 0.0024X,\ r = -0.7303,\ n = 47,\ P<0.0001 \quad (2)$$

There was an increase in the concentration of phosphorus in relation to the decrease in redox potential (Fig. 4).

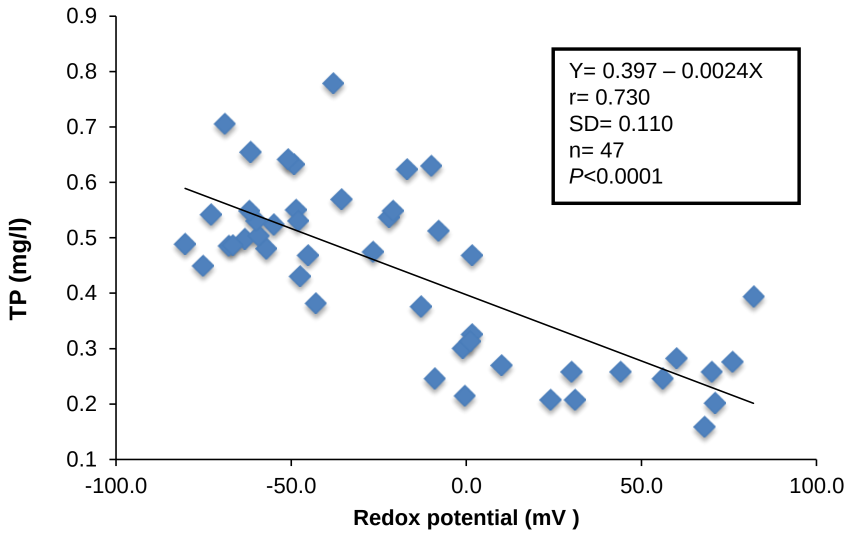

Fig. 4: Correlation between Total Phosphorus (TP) and the Redox Potential in the Batch System

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3.5. Total iron in overlying water

There is a close correlation between the concentrations of phosphate and iron in their different states of oxidation in overlying water. In this study, TFe slightly increased with increasing TP, reaching 0.35-16.44 and 0.16-0.78 mg/l, respectively. It is well known that at low oxygen concentrations, phosphate is adsorbed by Fe(III) to form solid complex iron-phosphate hydroxide. When the redox potential decreases, iron is reduced to Fe(II) and phosphate is released (Sundby et al., 1992). Fig. 5 shows a very weak relationship between TP and TFe:

Y= 0.376 + 0.0147X, r= 0.353, n= 47, P= 0.0150 (3)

This suggests that a large variation existed. The phosphorus and iron dynamics are demonstrated by the molar ratio of Fe to PO_4^{-3} at the end of the anoxic incubation (Fe:P release ratio). The release of phosphorus from sediment was investigated in shallow and eutrophic Lake Blankensee by Ramm & Scheps (1997); they reported that when the TFe:TP ratio (by weight) is greater than 21 in the sediment, phosphorus release is blocked. Jensen et al. (1992) reported that if the Fe:P ratio (by weight) is above 15, it may be possible to control internal P-loading by keeping the surface sediment oxidized. Although the sedimentary iron content must be higher than the concentration of phosphorus, iron phosphate formation is regulated by the concentration of sulfates and the formation of iron sulfides (Cooke et al., 1993). Smolders et al. (2017), suggests that internal loading of the P coming from sediments explains the soluble P ions concentrations which are most pronounced at low dissolved oxygen concentrations and in regions where the P/Fe ratio in sediment is large. In this study, the TFe:TP ratio fluctuated between 19 and 173 in the sediment. The TFe concentrations of the sediment samples ranged from 23 to 51 mg/g. This great variability in the Fe:P ratio explains the weak relationship between Fe and P in the overlying water, as shown in Fig. 5.

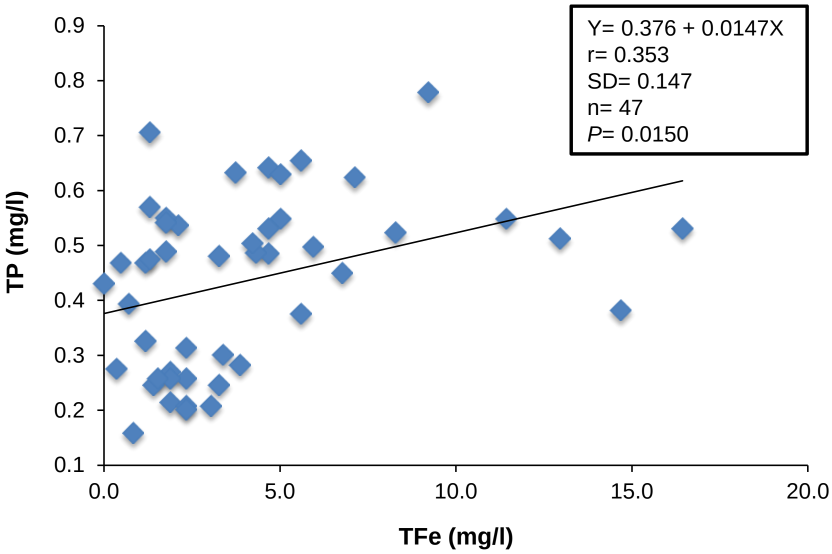

Fig. 5: Correlation between Total Phosphorus (TP) and Total Iron (TFe) in the Batch System

3.6. Phosphorus release flux estimated with the batch system and regression models

The phosphorus concentrations in water in the batch system were determined to quantify the amount of phosphorus released by the sediment to the water column in Lake Maracaibo (1976, 1983, 1998 and 2009), while those for 2023 were estimated with regression models. This P fluxes calculated are presented in Table 3.

Table 3: Estimates of Total Phosphorus Loading to Lake Maracaibo (kg/year x10^6)

Total phosphorus	1976	1983	1998	2009	2023
Estimated in Lake Maracaibo	43.73[a]	27.5[c]	15.44[d]	15.29[d]	33.52[f]
Contribution from sediments	4.87[b]	4.84	7.85	8.14[e]	9.20[f]
% sediment contribution	11.13	17.6	28.55	52.72	27.45

[a]Parra-Pardi (1979), [b]Ledo (1979), [c]Hansen et al. (2001), [d]Troncone et al. (2006a), [e]Torres (2012), [f]Regression models.

In the batch systems was estimated that 34 to 44% of the TP was released in the first 40 to 50 days and approximately 80% was released over the course of three months. Hupfer & Lewandowski (2005) estimated that approximately 60% of the settling particulate P is released within 2 weeks, approximately 80% is released within 0.5 year, and 85% is released during the total diagenesis. Based on the hypolimnetic P accumulation rates, the potentially mobile P in the sediment would be exhausted within three months. The release of P is generated by a continuous flux of settling phosphorus from the epilimnion rather than by a large inventory of temporary P stored in the sediment. Diagenesis in the upper sedimentary layers is so rapid that it prevents an accumulation of potentially mobile P. The results of this work are in agreement with those of Hupfer & Lewandowski (2005) regarding the rapid TP release from sediment; however, the phosphorus release rate from the Lake Maracaibo sediments was lower than that obtained by Hupfer & Lewandowski (2005) in Lake Arendsee, Germany.

A multiple linear regression model to describe the relationship between TP (dependent variable) and pH, TFe, and the redox potential (independent variables) was performed. The R-squared value indicates that the model, as fitted, explains 54.69% of the variability in TP. The equation of the fitted model is:

$$TP = 1.18327 - 0.11551 * pH + 0.00495242 * TFe - 0.00430484 * \text{redox potential} \quad (4)$$

The analysis revealed significant relationships between variables at the 95.0% confidence level ($P<0.05$). Because the *p*-value in the ANOVA table is lower than 0.05, there is a statistically significant relationship between the variables at the 95.0% confidence level. Predictive estimates through regression models, in order to know the TP contribution from sediments at the present time (2023), exhibited the following equations:

Estimated in Lake Maracaibo:

$$y = 0.0437x^2 - 175.16x + 175333, \ R^2= 0.9904 \ (\% \text{ error } 0.96) \quad (5)$$

Contribution from sediments:

$$y = -0.0011x^2 + 4.6651x - 4756.7, \ R^2= 0.9085 \ (\% \text{ error } 9.15) \quad (6)$$

Comparing the value of the release rate found in Lake Maracaibo with those of other lakes around the world, different release rates are observed for lakes with different degrees of eutrophication. For example, Lake Onondaga (USA) is a hypereutrophic lake (3-38 mgP/m^2.d) (Penn et al., 2000), Lake Tiefer (Germany) is considered a low eutrophic lake (3.04 mgP/m^2.d) (Selig & Schlungbaum, 2003), Lake Beaver (USA) is bordering on eutrophic conditions (0.57 mgP/m^2.d) (Sen et al., 2004), Lake Dudinghausen (Germany) is considered mesotrophic (0.35 mgP/m^2.d) (Selig & Schlungbaum, 2003), and Roundaway Lake (USA) is a hypereutrophic system (–3.7-3.3 mgP/m^2.d) (Evans et al., 2021). Based on the results of this study, Lake Maracaibo (Venezuela) is considered hypereutrophic (1.03 to 1.70 mgP/m^2.d).

3.7. Annual contribution to internal loads in Lake Maracaibo

The annual contribution of sedimentary phosphorus to the P content of the overlying water in anaerobic conditions was estimated based on the TP flux (between 1.03 and 1.70 mgP/m^2.d) and the sediment area in Lake Maracaibo (12,958 km^2). The contribution was found to be between 4.87 and 8.04x10^6 kg of P per year. The estimated annual loadings from external sources in Lake Maracaibo are shown in Table 3. The estimated sedimentary contribution to lake water between 1976 and 2023 comprises between approximately 11.13 and 52.72% of the external loading.

The results show a reduction in the external loading of phosphorus between 1976 and 2009 as a result of phosphorus resuspension from the sediments. The ICLAM (Instituto para el Control y Conservación del Lago de Maracaibo) used a mass balance model to conduct a study of Lake Maracaibo during the period between 1996 and 2006. Based on the amount of phosphorus in the model, it was observed that inflow from tributary rivers is the source of higher nutrients in Lake Maracaibo. The model could not measure the contribution of nutrients from the hypolimnion (the main internal source of nutrients) to the water column. Under this constraint, a concentration of available phosphorus in the lake of 15.44x10^6 kg/year was obtained, and subsequently, 6.39x10^6 kg/year of TP was estimated to be trapped in the sediment (Troncone et al., 2006a). The value of 15.44x10^6 kg/year was taken for the year 1998, as shown in Table 3. The amount of phosphorus loading from sediment in this laboratory experiment in 1998 was estimated to be 7.85x10^6 kg/year, which is similar to the value of 6.39x10^6 kg/year estimated by ICLAM using the mass balance model. In 2006, Troncone et al. (2006a) estimated that 100% of the wastewater flow to Lake Maracaibo would be treated between 2007 and 2012; assuming a 100% reduction in the available phosphorus in the lake, that would be 15.29x10^6 kg/year. This was the estimated value for 2009, as shown in Table 3.

The behavior of TP internal charges seems to reveal a cyclical phenomenon in this ecosystem, whose concentrations regain strength according to the predictions for 2023 (Table 3). These abrupt increases in TP concentrations could explain the temporary planktonic blooms observed in the lake, for example during 2004-2005 and July-2023 where excessive growths of the *Lemna obscura* (Kiage & Walker, 2009; NASA, 2023) and the *Microcystis* sp. (Esconusted, 2023) were reported, respectively. These events highlight the increase in nutrient concentrations in the water as a result of the discharge of untreated wastewaters and the increase in river flows due to excessive rainfall this year (El Niño effect), which contribute nutrients from agricultural land south of the lake. This increase in flows of tributaries that push the water masses towards the lake center acts as a trigger to erode the structure of hypolimnetic cone, causing the release of nutrients confined in the sediments of this area (Parra-Pardi, 1979), among others factors.

3.8. Comparison of phosphorus values in the batch system and *in-situ* in Lake Maracaibo

The concentrations of phosphorus at the beginning and at the end of the batch system experiment were 0.251 and 0.253 mg/g, respectively. The values of these phosphorus concentrations are quite similar, which indicates that the batch system successfully simulated the natural conditions of the lake. Using the batch system is a convenient way to evaluate phosphorus adsorption and release processes in sediments.

IV. CONCLUSIONS

The parameters with the greatest influence on P release in sediments from the hypolimnetic cone in Lake Maracaibo are the iron concentration and redox potential. These two variables explain the 54.69% of the TP variability in the overlying water. The release of sedimentary TP in Lake Maracaibo is a rapid process. It was estimated that approximately 80% of the TP may be released from sediments over the course of three months. Under anaerobic conditions, the annual contribution of the released phosphorus to the P content of overlying water ranged from 4.84 to 8.14×10^6 kgP/year, accounting for approximately 11.13-52.72% of the external P loading. The cycling phenomenon observed in the external loading of phosphorus between 1976 and 2023 with increases in 1976 and 2023 and decreases in 1998 and 2000, causes great variability in the P concentrations in the lake water, which results mainly P release from sediments. The study of phosphorus transfer across the water-sediment interface in the Lake Maracaibo system, particularly internal phosphorus loading, provides additional valuable data for implementing measures to mitigate the acceleration of the process of eutrophication in tropical reservoirs. The batch system used in this work successfully simulated the natural conditions of the lake.

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Determination of Levels of Heavy Metals in Soils at Suame Magazine

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Abstract— *Background and objectives of study; Auto mechanics in Ghana have positively contributed to the transportation sector. However, they leave behind diverse waste materials on the soil within their workshops and the surrounding areas. These materials contain heavy metals, which in high concentrations, negatively effects the nervous, reproductive and vascular systems. This research aims at determining the levels of heavy metals such as lead, zinc, chromium and cadmium at the magazine. The results shall indicate the extent of pollution of the soils, and thereby contribute to data on heavy metals in Ghana. Methods: Fourteen soil samples were collected from two zones at Suame magazine in Kumasi in the Ashanti region of Ghana. Seven (7) samples from the spare parts dealers (lower zone) and the other seven from the working site (upper zone).The samples were digested and the concentrations of the metals determined by the Atomic Absorption Spectrophotometer. Results: Zinc had the highest concentration of 58.52 mg/kg and the least being chromium with concentration of 1.70 mg/kg. These concentrations were within the permissible limits of WHO. Conclusion: Heavy metals concentration was higher at where artisans work and low at the spare parts zone.*

Keywords— ***Auto mechanic workshop, Heavy metal uptake, soil pollution, soil samples.***

I. INTRODUCTION

Heavy metals are chemical elements mostly with density greater than 4 g/cm3. They include metals, such as Fe, Zn, Cd, and Pb. Human activities are blamed for soil pollution arising these heavy metals. (Masindi and Muedi, 2018).[1]

In Ghana, auto mechanics /artisans play a major role in the maintenance of vehicles and thereby generate varieties of waste materials via disposal of dirty engine oil, vehicle battery acid water, carbide from welding and metal scraps (Marahatta et al., 2018)[2]. Other sources include spraying, painting, and combustion processes (Pam et al., 2013) [3] . which may lead to risks in human health and the environment especially when they enter the food chain (Adelekan & Alawode, 2011) [4].

Soil, as a widespread receptor, naturally contains significant quantities of heavy metals, which vary in concentration depending on various sources, whether they are of natural or human origin (Adelekan & Alawode, 2011) [5] .

For so many decades, environmentalists and scientists in ecotoxicological studies have used the phrase “heavy metals”. Heavy metals have been widely employed in many industrial applications such as manufacturing of batteries, alloys, electroplated metal parts, agro-chemical applications, and road constructions [6]. Heavy metals which have densities about 5 times greater than density of water [7], are non-biodegradable and are therefore monotonously contaminating the air, deposited into soil, water, as well as sediments [8] . The presence of heavy metals in the environment has aroused great concern due to their potential long-term detrimental effects on human, animal, and plant life particularly in developing countries where mitigation processes are fledgling [9]. For instance, the degeneration of spermatogenesis and semen quality in human male, has been attributed to Cd contamination [10], hypertension and other cardiovascular have been attributed to Pb exposure even at low levels, and the adverse alteration of neurological, nervous, digestive, immune, and reproductive systems in humans and wildlife has been linked to Hg pollution [11].

Human exposure to heavy metal toxicants in surface soils usually occurs through suspended dust inhalation, oral ingestion, and dermal contact [12]. Surface soils instead of other soil horizons usually record higher levels of heavy metals as a result of human activities [13]. Elevated levels of the toxic` metals defy goals 1 and 3 of the Africa Union's Agenda 2063 [14]. That is, they represent a momentous threat to quality of life and well-being for all citizens, as well as impede living resources and ecological systems because of their increased discharge, poisonous nature, and other adverse effects on the environment.

About 20% of the total burden of disease in the developing countries is due to environmental pollution. Therefore raising awareness and increasing efforts to reduce the risk of pollution, including heavy metal pollution, would further decrease the burden of disease, and therefore, improve the well-being of the population and hence increase productivity. The aim of this study therefore is to monitor the extent of heavy metal pollution in selected areas of the magazine and automobile waste disposal deposition of particulate matter from the atmosphere, the disposal of sewage sludge and effluents enriched with metals, and the by-products generated during metal mining processes. Soil serves as a significant repository for human-generated waste. Through biochemical processes, these heavy metals can be mobilized, leading to water pollution and impacting food chains. Heavy metals such as copper (Cu), chromium (Cr), cadmium (Cd), nickel (Ni), and lead (Pb) pose a potential risk as soil and water pollutants. The issue of environmental pollution caused by heavy metals has become a global concern, especially in major cities, as it can result in the accumulation, bioaccumulation, and biomagnification of these contaminants within ecosystems. Eventually, heavy metal contaminants in the environment are deposited in soils in forms of low solubility compounds like pyrite (Huerta-Diaz & Morse, 1992),[6] or they become sorbed onto reactive surface phases such as iron (Fe) and manganese (Mn) oxides (Cooper, Neal, Kukkadapu et al., 2005; Hamilton, Smith, Davison & Sugiyama, 2005).[7]

II. MATERIAL AND METHODS

2.1. Study Area

The Suame industrial area also known as magazine is an integral part of Kumasi in the Ashanti Region, Ghana. It lies at latitude 06º43'21.26"N and longitude -1 º38'40.19"W.The area sees many forms of industrial use, such as car body part repair, auto mechanic shops , metal fabrication workshops and manufacture of aluminum and silver utensils. Also present are blacksmiths, carpenters, and car paint sprayers. Suame is also known for vigorous commercial activities including trading in all kinds of automobile spare parts, building materials and electrical appliances.

Figure 1 shows the sampling sites at the magazine.

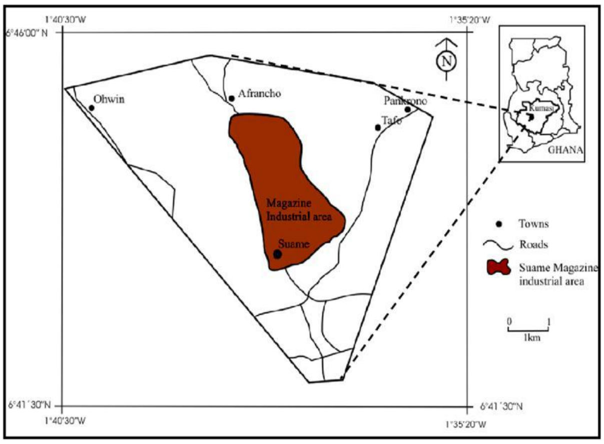

Fig.1: Location of sampling at Suame magazine

2.2. Collection of samples

Soil samples were taken from the surface of the soil at 0-10 cm depth with the aid of a core sampler. The sample site was divided into two zones namely; the lower part (area of spare parts dealers and houses) and upper part (artisans working area). Seven Soil samples were taken from each zone to make a total of 14 soil samples. Quadrat and core sampler were used in the collection of the sample. The quadrat was placed at a place in the upper part, the core sampler was then used to take spoil samples at a depth of 0-10 cm taken three soil samples from the quadrat. This step is then repeated twice to give six soil samples from the upper zone. This procedure is repeated at the lower zone to get a sum of 12 samples from the two zones. Two additional soil samples were taken at random making a total of 14 samples. The samples were labelled separately, and sent to the laboratory for analysis.

2.3. Laboratory analysis of sample

Soil samples were labelled for easy identification. The soils were air-dried and digested to determine the concentration of the heavy metals by the AAS.

0.5M EDTA was prepared by weighing 18.64g of the EDTA into a 2L flask, ammonium acetate was added, dissolved and topped to the mark with deionized water.
Five (5) g of the soil sample was added to 25mls of EDTA solution. The mixture was shaken for two (2) hours with a mechanical shaker at 180 rpm. The mixture was filtered and the filtrate was analysed for Zn, Cr, Cu and Pb using AAS.

III. RESULTS

This section highlights the various results obtained and describes the trend in accumulation at both zones, and compared to FAO/WHO acceptable limits in soils.

Table 1: Concentration (mg/kg) of Heavy Metals in the Soil Samples.

Samples	**Lower Zone**				**Upper Zone**			
	Pb	Zn	Cr	Cd	Pb	Zn	Cr	Cd
1	10.63	32.61	3.046	3.547	15.432	58.52	4.459	5.827
2	12.63	35.47	3.242	3.569	15.219	56.89	4.265	4.049
3	12.57	32.84	3.391	3.902	15.128	55.64	4.218	4.984
4	13.52	25.85	2.868	4.326	18.432	36.42	5.496	8.182
5	11.58	28.30	2.163	4.439	18.332	48.95	5.323	8.051
6	13.60	25.68	2.114	4.542	18.541	48.57	5.361	8.095
7	14.09	40.37	1.705	2.215	16.321	34.68	2.987	3.839
WHO/FAO (2001)	**50**	**300**	**50**	**3**	**50**	**300**	**50**	**3**

Source: Bartels/ Mensah laboratory results, 2023

Table 2: Mean Concentrations of Heavy Metals (mg/kg)

	Upper zone	**Lower zone**
Heavy metals	**Mean concentration**	
Pb	**12.66±0.462**	**16.77±0.601**
Zn	**31.59±2.032**	**48.52±3.647**
Cr	**3.79±0.735**	**6.15±0.735**
Cd	**2.65±0.245**	**4.59±0.337**

IV. DISCUSSION

The average concentrations of some of the heavy metals detected in a control soil at the Central Agricultural Research Station at Kwadaso, Kumasi were Pb: 9.5 mg/kg, Cd: 7.2mg/kg and Zn: 15 mg/kg (Sadick et al .,2015) [15]. This indicates that the metal concentrations at the study site exceeded those of the control even though the sites are just 5.3 km apart. This corroborates the finding that areas with higher tempo of anthropogenic activities of urban settlements have high soils contaminants (Adelekan and Alawode (2011) [16]

The Zinc content had a mean of 31.59±2.032 and 48.52±3.647 at the lower and upper zones respectively as shown in Table 1. These values are higher than the control and suggest an anthropogenic contribution, and solely attributed to the contribution from the auto mechanic shops, since Zn is an additive of lubricating oils (Abenchi et al., 2010) [17]. The values of Zn obtained in the study area conform to the acceptable limit of 50 mg/kg (Lacatusu, 2000) [18].

The mean concentration of Cd in the study area was 2.65±0.245 and 4.59±0.337 mg/kg in the lower and upper zones respectively. The main source of environmental Cd pollution is the ferrous-steel industry (Onder et al., 2007)[19], the accumulation of Cd in the area is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts (Dabkowska - Naskret, 2004)[20]. The Cd concentration was above the WHO/FAO acceptable limit of < 3mg/kg as indicated in Table 1. This concludes that the soils at Suame magazine are highly polluted with cadmium than other heavy metals.

The mean value of Pb in soils obtained in this study was 14.72 mg/kg, higher than the control, 9.5 mg/kg and could easily be attributed largely to the activities in the auto mechanic shops. Lead has the highest composition of heavy metals in waste oils (Oguntimehin et al., 2008)[21] and that high concentration of Pb in the study area could be due to the waste oil, and expired motor batteries indiscriminately dumped.

The mean concentration of chromium was 4.59 mg/kg, and below the WHO/FAO permissible limits of 50 mg/kg in soils as shown in Table 1. The control soil however did not reveal any traces of chromium in the study area. Chromium is a highly toxic heavy metal that can have adverse effects on human health and the environment. It is crucial to address and remediate the elevated levels of chromium to mitigate the associated health and environmental risks.

The soils at Suame magazine recorded high concentrations of heavy metals than the control plot located just 5.3km apart. Hence, the soils at Suame magazine can be said to be polluted by the activities of the artisans though the levels of pollution were found to be within the permissible limits of WHO/FAO with the exception of Cadmium which was found to be significantly higher than the permissible limit.

V. CONCLUSION

1. The mean concentrations of lead, zinc and chromium in soils at the automobile workshop were within the permissible limits recommended by WHO/FAO.

2. Cadmium, however, recorded concentrations above the permissible limits of WHO.

3. Soils at Suame magazine are polluted relative to the control plot.

4. The artisans are the prime contributors of heavy metal pollution at Suame magazine.

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RECOMMENDATION

- The artisans need to be educated about the negative consequences of improper disposal of spent fuels and battery acid on the environment.
- Workshops should create special waste chambers for proper disposal to prevent the spread of heavy metals, especially into nearby fields where crops are cultivated.

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Analysis the Potential of Malang Regency as a Center for Oil Palm Plantations in East Java

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***Abstract*— East Java region is known for its good land potential for agriculture. One area that has a large enough agricultural land is Malang Regency. This feasibility study in the long run can become the foundation for establishing oil palm plantations and also a palm oil processing industry in the region. Thus, a feasibility study of various important aspects is carried out for the sustainability and sustainability of the development of the oil palm plantation industry in Malang. The purpose of this study is to see how land and environmental conditions suitability and to study and map the suitability of oil palm land in Malang Regency. The study was carried out in October - December 2021 in the southern Malang region and the southern Blitar location as a comparison area and industrial survey to find out data on oil quality in the southern region of Malang Regency and Blitar. Studies use survey methods to describe situations and events with the aim of solving problems in a systematic, fluctuating and accurate manner regarding the facts and characteristics of a particular population or area. Land suitability variables are in the form of geographic data, such as slopes and determination of points; macro climate data and micro climate data, such as radiation intensity, RH, temperature, flood potential and soil data including physical properties, such as soil texture, structure and depth; biological properties, such as c-organic content, litter thickness and presence of earthworms and chemical properties, such as analysis of N, P and K content, pH and base saturation and soil CEC. Based on a comparison of soil analysis data in the areas of Malang, Sumatra and Kalimantan, it can be said that the land suitability of Malang Regency is in accordance with the needs of oil palm plants based on land suitability.*

***Keywords*— Land suitability, climate type, oil palm, nutrients**

I. INTRODUCTION

One of the most important and strategic plantation commodities in Indonesia's economy is palm oil. This is because palm oil is the main ingredient for cooking oil that is widely used by the people of Indonesia, so that the supply and sustainability of raw materials must increase to meet the needs and stability of cooking oil prices. Cooking oil is the main product of palm oil and is one of the staple foods in Indonesia. Second, as one of the leading agricultural commodities for non-oil and gas exports, this commodity has good prospects as a source of foreign exchange and state taxes. Third, the process of cultivation and post-harvest production (processing) is also able to create job opportunities and improve people's welfare, especially in the oil palm plantation industry.

Land suitability is the level of suitability of a piece of land for a particular use. Even though plants seem to be able to grow in a field, each type of plant has different characteristics. According to Rayes (2007), states that land use that is in accordance with the conditions for growing plants will provide optimum results and maintain the sustainability of land use. In line with the opinion of Husna, (2015). To get maximum results from cultivation, land suitability is very important. Especially in oil palm plants, regardless of oil palm can grow in a variety of available land conditions, but each plant has a character that requires different needs. Land suitability classes are prepared by comparing (matching) the characteristics of the land/climate in each map unit with land suitability criteria (plant growth requirements). Therefore, selecting suitable land for certain crops can reduce land use impacts and increase yield potential (Everest et al., 2020; Karmakar et al., 2016). Suitability for agriculture is represented by climate, soil, water resources, and topography (Hamdani et al., 2017; Ahmed et al., 2016).

The East Java region is known for its good land potential for agriculture. One area that has a large enough agricultural land is Malang Regency. Commodities that are often found in the region are food commodities, such as corn and rice, but several plantation commodities such as sugar cane and tobacco are also found. In several areas in Malang, small-scale oil palm plantations are found. So with the initial assumption that the feasibility of cultivating oil palm in Malang can be developed. This feasibility study in the long run can become the foundation for establishing oil palm plantations and also a palm oil processing industry in the region. Thus, a feasibility study of various important aspects is carried out for the sustainability and sustainability of the development of the oil palm plantation industry in Malang. The purpose of this study is to see how land and environmental conditions suitability and to study and map the suitability of oil palm land in Malang Regency.

II. BAHAN DAN METODE

The study was carried out in October-December 2021 in the southern Malang region and the southern Blitar location as a comparison area and industrial survey to find out data on oil quality in the southern region of Kab. Malang and Blitar. Studies use survey methods to describe situations and events with the aim of solving problems in a systematic, fluctuating and accurate manner regarding the facts and characteristics of a particular population or area.

The variables observed included land suitability and agronomic data as well as agricultural socio-economic data. Land suitability variables are in the form of geographic data, such as slopes and determination of points; macro climate data and micro climate data, such as radiation intensity, RH, temperature, flood potential and soil data including physical properties, such as soil texture, structure and depth; biological properties, such as c-organic content, litter thickness and presence of earthworms and chemical properties, such as analysis of N, P and K content, pH and base saturation and soil CEC.

III. RESULTS AND DISCUSSION

Geographical suitability

In theory, the actual coordination and actual elevation in the southern Malang region, especially in the Donomulyo, Bantur and Blitar districts are in accordance with the conditions for growing oil palm. Where in coordinates, oil palm grows in the wet tropics with coordinates $112^0$17' to $112^0$57' BT and $7^0$44' LS – $8^0$26' and in elevation, oil palm grows in the lowlands with an altitude of 0-500 meters above sea level. According to (Sasongko, 2010) oil palm will develop optimally in geographical conditions 15 °N-15 °S, the ideal altitude ranges from 0-400 m above sea level, rainfall is 2,000-2,500 mm/year, the optimum temperature is 29-30 °C, the intensity of sunlight is around 5-7 hours/day with an average irradiation of 6 hours/day, the optimum humidity is around 80-90%. On the island of Sumatra, one of which is in the area of Kampar Regency, Riau Province, oil palm can be developed at 0^0 12'-0^0 20' north latitude and 101^0 14'-101^0 24' East longitude (Wigena*et al.*, 2009). The average amount of annual rainfall is 2,339 mm yr^{-1}, the average annual air temperature is 26.4^0 C and average humidity of 81.2%. These geographical conditions are very suitable for the growth and development of oil palm (Wigena*et al.*, 2009). This shows that the area of Kampar district, Riau province is geographically very suitable for developing oil palm.

Kalimantan Island, one of which is in the Marabahan sub-district, Barito Kuala Regency, South Kalimantan Province, has geographical suitability for oil palm plantationsbetween 1°21' 49″ – 4°10'14″ South Latitude and 114°19' 13″ to 116° 33' 28″ E. Average rainfall 2000-2500 mm $year^{-1}$, optimum temperature of 29 °C (Arisanty & Syarifuddin, 2018). This shows that the area of the Marabahan sub-district, Barito Kuala Regency, South Kalimantan Province, is geographically very suitable for developing oil palm commodities. When compared with Blitar Regency which is south of the Equator. Precisely located between 111°40' - 112°10' East Longitude and 7°58' - 8°9'51" South Latitude (Sasongko, 2010). Blitar Regency has its capital in Blitar, this district is bordered on the north by Kediri Regency, to the east of Malang Regency, to the south of the Indian Ocean, and Tulungagung Regency to the west. Mount Kelud (1,731 masl), one of the active volcanoes on the island of Java which is located in the northern part of this district is directly adjacent to Kediri Regency. from its geographical suitability, the Blitar district is suitable for developing oil palm commodities. An understanding of the characteristics of the soil in oil palm plantations is needed as a basis for determining the technical cultural actions to be carried out in order to ensure the continuity of land productivity (Firmansyah, 2014).

Climate Suitability

Based on the results of climate classification calculations according to Oldeman in the last 20 years in Malang Regency, the climate type for Malang Regency is C3. The results of the analysis of climate types in Malang Regency are shown in Table 1.

Table 1. Results of type analysis in Malang Regency

Year	Monthly average wet	Monthly average dry	Climate type
1999-2008	5	6	C3
2009-2018	5	5	C3

In theory, oil palm can grow well in climate types A, B, and C (Oldeman) thus the results of the analysis show that the climate type in Malang Regency is classified as C3 suitable for oil palm plantations.

Table 2. Solar radiation from field measurements at ground level in oil palm plantations

Year	Donomulyo Gardens	Banter	Kromengan
RTC (%)	35	36	40

The results of rainfall each year differ with the highest rainfall in 2016, namely 3269 mm and the lowest in 2018 with rainfall 1614. Oil palm plants have a very important function in plantation development, through this plantation sector it can create jobs that affect the public welfare. The growth and development of oil palm plants is highly dependent on environmental factors. Oil palm plantations in Indonesia are growing rapidly, in 2019 it was recorded that the land area reached 16.4 million hectares where 40.6% of the area is smallholder plantations, 55% large private plantations and 4.4% national plantations (Sardjono, 2020). One area that has the potential to develop oil palm cultivation is Sumatra, Kalimantan and Java.

Each region has different climatic conditions. The ideal rainfall for oil palm plants ranges from 2000-2500 mm per year and is evenly distributed throughout the year while the optimum temperature for oil palm plants is between 22-23^{O}C. When compared with the regions of Sumatra and Kalimantan in the previous data, the Malang district area is suitable for oil palm plantations. According to Sirgaret al., (2014) climatic elements that have a dominant influence on oil palm plantations in Indonesia are rain, solar radiation and air temperature (in the highlands). Rainfall is an important factor for flower development and oil palm bunch production. In general, during the rainy season, more female flowers are formed, while during the dry season, more male flowers are formed (Tumer, 1978). Oil palm can grow well optimally in the wet tropics (12^{O} north latitude – 12^{O} south latitude) with Af and Am (Koppen) climate types. This will directly affect the productivity of palm oil. In line with the opinion of Pahan, (2006). For its growth, oil palm requires an average annual rainfall of around 2,000 mm year-1 no dry months Groundwater stress (drought) will show a sharp decline in production due to an increase in the number of male fruit bunches. Optimum average annual air temperature range for oil palm 25^{O}C - 28^{O}C, but can still produce at an average annual temperature between 24^{O}C - 38^{O}C. The combination of rainfall and air temperature is very likely to play a role in the mechanism of opening and closing leaf stomata which leads to photosynthesis (Risza, 2008).

Information on Soil Quality Comparison of Oil Palm and Non Oil Palm Plantations

Based on the results of laboratory analysis, the percentage of water content in 3 sub-districts in South Malang was 7.11 to 8.58 percent. Oil palm requires high amounts of fresh water for effective yields (Gheewala et al., 2014; Silalertruksa et al., 2017). Therefore, even though overall soil quality may be suitable for oil palm, low groundwater regeneration can be a serious concern impacting yields.

The role of nitrogen in oil palm plants is very important, if nitrogen needs are not fulfilled plant growth will be disrupted. The results of soil analysis showed that the percentage of total N in 3 sub-districts in South Malang was 0.13% to 0.28% percent (Figure 1). This shows that the total N% content of the soil at the study site is low. The low nitrogen is thought to be because nitrogen is lost easily through washing or evaporation (Darlita et al, 2017). In line with the opinion of Rajmi et al., (2018) the low N is thought to be because N is lost easily through leaching due to rainwater or evaporation. According to low N levels, it can also be caused by microbial activity in the soil, thus affecting the absorption of nitrogen nutrients in the form of N available to plants, because plants take nitrogen in the form of NH_4^+ and NO_3. In the soil there is 99% N in organic form, only 2 – 4% of it is mineralized into inorganic N (NH_3^+) (ammonification) by various heterotrophic microbes, then some of it undergoes nitrification (Saputra et al., 2018, Hanafiah, 2005). The role of element N is very important which is an integral part of chlorophyll and is the main component of plants absorbing the light needed in the process of photosynthesis (Barker et al., 2007; Saputra et al., 2018). According to Darlita et al (2017), soil chemical properties such as N-total, CEC, and Al-dd are parameters that increase the number of bunches per tree. There are several factors that result in limited availability of N in soil, including (1) the nature of nitrogen which is very mobile, (2) leaching of N nutrients by rainwater, (3) transported during harvest, (4) bound by soil minerals, and (5) utilized by organisms (Ginting et al. 2013; Sakti et al., 2011).

Nutrient P is a macro nutrient that is needed by plants after N and more than K. The analysis results show Total P2O5 in 3 sub-districts in South Malang of 17.76me/100g up to 23.12me/100g which is classified as very high, when viewed based on the criteria for assessing soil fertility. Phosphorus (P) is an absolute element needed by plants because it plays a role in storing and transferring energy as well as a component of protein and nucleic acids. Based on this, a high supply of P nutrients is shown by the development of branching roots and faster fruiting (Pakpahan et al., 2019; Fahmi et al., 2010). According to Umaternate et al. (2014) said that the P element that can be absorbed by plants is in the form of $H_2PO_4^-$, HPO_4^{2-}, and PO_4^{3}- in soil solution. Factors that affect the availability of P in the soil are (1) C-organic, (2) soil pH, (3) the content of Fe, Al, and Ca, and (4) the physical characteristics of the Jajang soil, (2021).

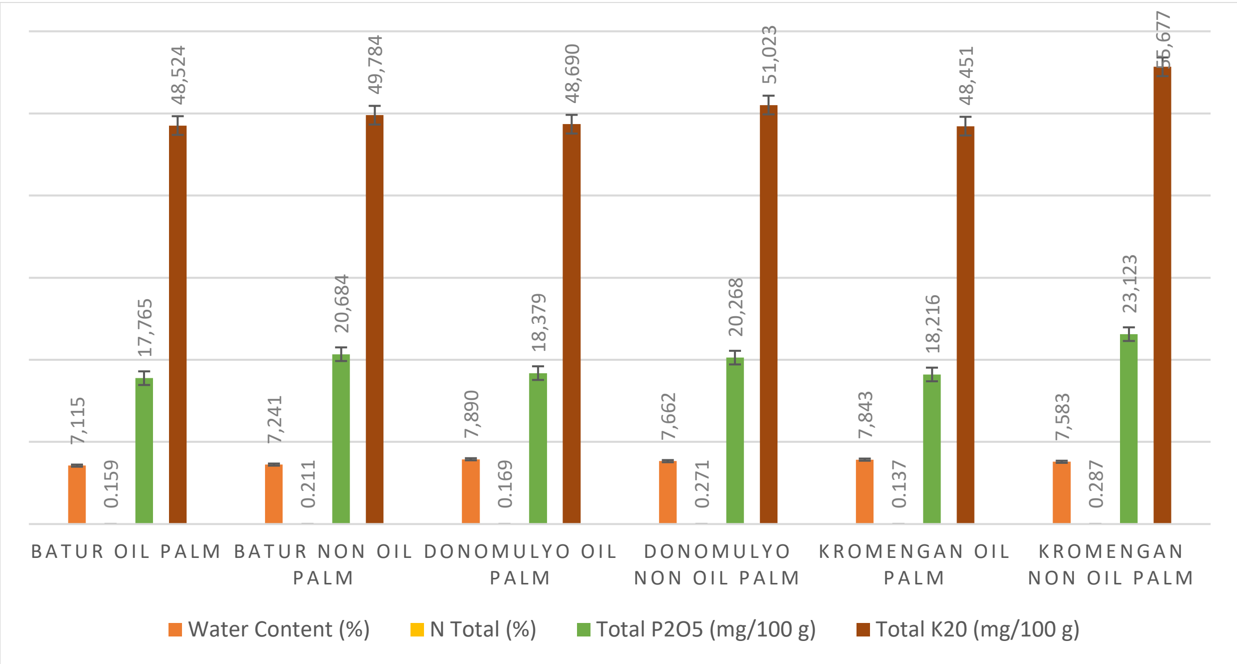

Fig.2. Comparison of Water Levels, P_2O_5, N-Total and K_2O Land of Oil Palm and Non Palm Oil Plantations in Malang Regency

Based on the results of laboratory analysis, the total K20 in 3 sub-districts in South Malang was 48.45 me/100g to 55.67 me/100g which was classified as very high. According to Ginting et al., (2013), the range of balanced nutrient ratio values for oil palm plants is 5.6-10.1 for Ca/K, 2.1-2.5 for Ca/Mg and 2.1 respectively. -4.5 for Mg/K. (Corley & Tinker, 2003) stated that the optimum soil balance for K:Ca:Mg for oil palm cultivation is 10:60:30. K elements absorbed by plants in the form of K+ ions. A positive charge will help neutralize the electric charge formed by nitrate, phosphate, Ca, Mg, and other elements (Rahma et al., 2014; Suseno et al., 2018). Element K, together with elements N and P, is one of the most important primary macronutrients for plants during their growth process. Element K is absorbed by plants from the soil in the form of K+ ions, and is abundant in ash. Young tea leaves contain 50% K2O, and young cane shoots contain between 60 and 70 percent K2O. The elemental K content in plant tissues ranges between 0.5 and 6% of their dry weight. Assimilation will stop if K is not given (Pakpahan et al., 2019).

Based on the results of the analysis, the percentage of total N in the Secanggang District, Langkat Regency, North Sumatra Province was 0.15. The percentage of P2O5 is 4.52 (ppm). The percentage of K2O is 0.81 (mg) (Nora, Manullang and Wijoyo, 2020). Based on the results of laboratory analysis, the percentage of total N in Seruyan District, Central Kalimantan was 0.13 percent. The percentage of C-org is 0.77 to 1.8 percent. Percentage P 48.14 to 88.16 (ppm). Percentage of K 10.65 to 13.73 ($mg.100g^{-1}$) (Prasetiaet al., 2017). According to Sollyet al. (2019) pH, cation logam dalam tanah, KTK (kapasitas tukar cation), dan kandungan nitrogen (metals in the soil, CEC

(Cation Exchange Capacity), and nitrogen content) (Gärdenäs et al. 2011).

Based on a comparison of soil analysis data in the areas of Malang, Sumatra and Kalimantan, it can be said that the land suitability of Malang Regency is in accordance with the needs of oil palm plantations. The value of P and K elements in Malang plantation land is quite high. Meanwhile, in poor plantation areas, the N element content is still relatively low. Thus Malang plantation land can be said to be suitable for land suitability even though there is a limiting factor for N nutrients which can be overcome by adding fertilizer to support the growth and yield of oil palm plants. Good soil chemical properties mean that the soil can provide nutrients in sufficient quantities and are available to be absorbed by plant roots. (Mawardati, 2017; Rahmah et al., 2014). Oil palm fertilization is important due to the low ability of acid mineral soils to provide nutrients, the high retention of nutrients by the soil and the genetic nature of oil palm plants that require large amounts of nutrients compared to other plants (Rahman et al., 2018; Adiwiganda, 2002).

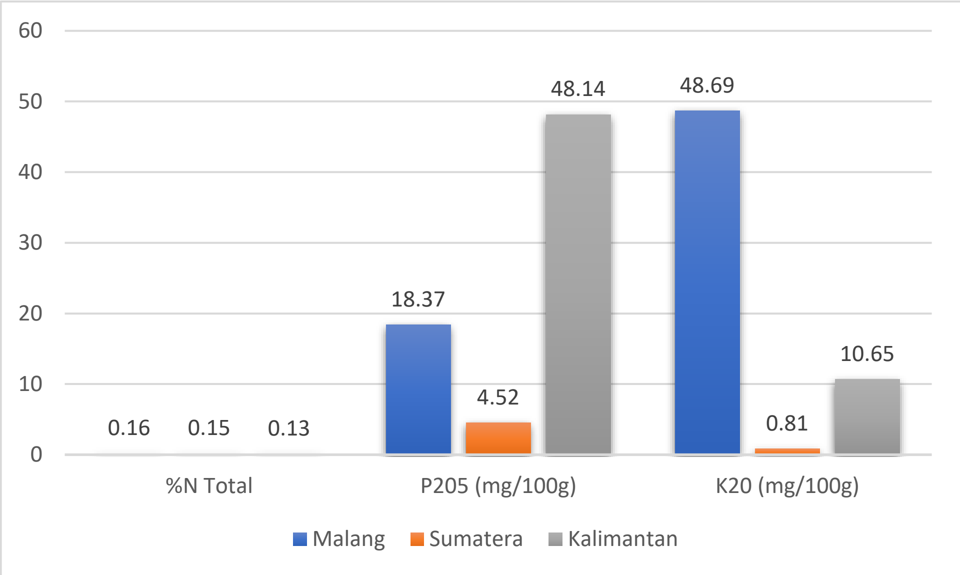

Fig.2. Comparison of the N, P and K content of oil palm plantations in Malang Regency

To increase and maintain the productivity of these soils, it is necessary to apply fertilization, especially macro-fertilizers, so that palm oil production is optimal. Therefore, in plant maintenance, the cost required for fertilizing dominates the maintenance cost which is around 60% of the total cost (Ginting et al., 2019;Koedadiri et al., 2005; Adiwiganda, 2002). The high need for nutrients in oil palm is related to the high production produced. On land with an S1 suitability level, the average FFB production is around 25.0 tons of FFB ha^{-1} year^{-1}. The content of nitrogen, phosphorus, potassium, calcium, magnesium and sulfur at these production levels is 74 kg N, 11 kg P, 93 kg K, 19 kg Ca, 20 kg Mg and 14 kg S respectively (Fairhust, 2002) . In line with the results of this study, it was reported that on dry, acidic land, to produce 27 tons of FFB, it was necessary to enter nutrients from outside the soil-plant system in the form of fertilizer of 190 kg N, 26 kg P, 257 kg K, 43 kg Ca, 40 kg Mg, and 60 kg S (Moody et al., 2003).

IV. CONCLUSION

1. Based on geographic analysis 112^{O}17' to 112^{O}57' East longitude and 7^{O}44' South latitude - 8^{O}26' South latitude (classified as wet tropical), climate type C3 indicates that Malang Regency is suitable and feasible for oil palm cultivation.
2. The potential of agricultural land in the district. Malang is still sufficient for the development of oil palm, it's just that sustainability aspects, especially the environment, need to be considered.

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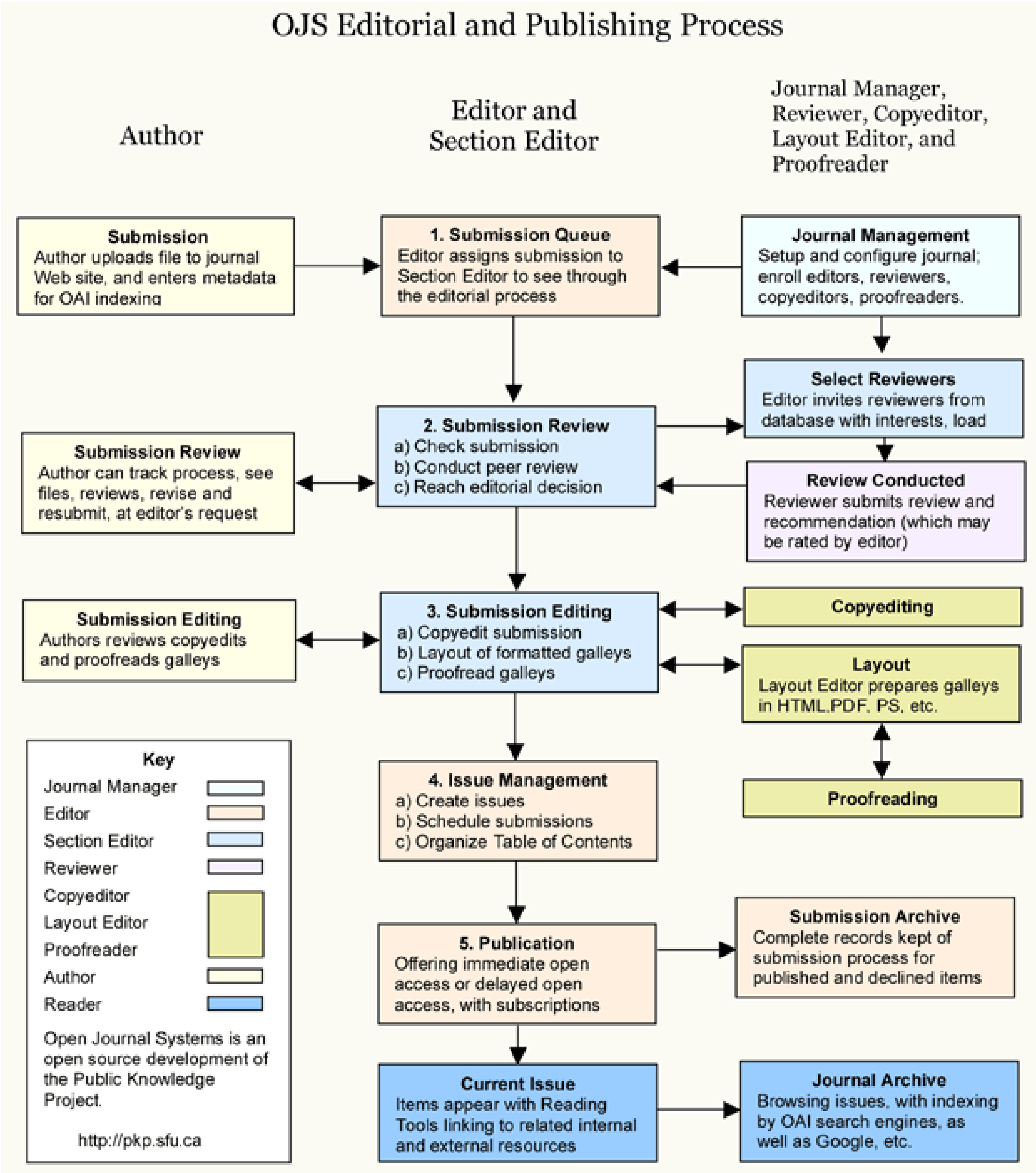

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