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Rice Intensification in the Fogera Wetlands: The Need for Institutional Linkage and Environmental Trade-offs to Sustain Lake Tana Biosphere Reserve

By

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ACRONYMS

ANOVA	Analysis of Variance
ANRS	Amhara National Regional State
BoEPLAU	Bureau of Environmental Protection and Land Administration and Use
BR	Biosphere Reserve
CBD	Convention Biological Diversity
CBC	Community-Based Conservation
CBNRM	Community based natural resource management
CHIRPS	Climate Hazards group Infrared Precipitation with Stations
COV	Coefficient of variation
Cp	Chickpea
CPR	Common Pull Resources
CSA	Central Statistical Agency
DEM	Digital Elevation Model
DM	Dry Matter
e	error term
EIA	Environmental Impact Assessment
EiABC	Ethiopian Institute of Architecture, Building Construction and City Development
EPA	Ethiopian Environmental Authority
EROS	Earth Resources Observation System
ETB	Ethiopian Birr
ETM	Enhancement Thematic Mapper
EWNRA	Ethiopian Wetlands and Natural Resources Association
FAO	Food and Agricultural Organization of the United Nations
FGD	Focus Group Discussion
Fig	Figure
FYM	Farm Yard Manure
GL	grazing land per household
GOs	Governmental Organizations
Gp	Grass pea
GPS	Geographical Positioning System

Ha	Hectare
IBC	Institute of Biodiversity Conservation
IHA	Indicators of Hydrological Alteration
ILRI	International Livestock Research Institute
IPCC	Intergovernmental Panel on Climate Change
IPMS	Improving Productivity and Marketing Success
IWRM	Integrated water resources management
Kg	Kilogram
LSM	least squares means
LULC	Land use/land cover
MAB	Man and Biosphere
MEA	Millennium Ecosystem Assessment
MODIS	Moderate Resolution Imaging Spector-radiometer
MoWEM	Ministry of Water, Energy and Minerals
MoWIE	Ministry of Water, Irrigation and Energy in Ethiopia
MSS	Multi Spectral Scanner
N	Nitrogen
n	Total household sample number
N	Total population
NABU	Nature and Biodiversity Conservation Union
NDVI	Normalized difference vegetation index
NGO	None Governmental organization
NRC	National Research Council
NRRDS	National Rice Research and Document Strategy
NSE	Nash–Sutcliffe efficiency
P	Phosphorous
qt/ha	quintal per hectare
Resi	Residue
RFC	Rice Fish Cultivation
SAS	Statistical Analysis System
SD	Sustainable Development
SEM	Standard error mean

Skm	Square kilometer
SPSS	Statistical Package for Social Science
SRTM	Shuttle Radar Topography Mission
STDEV	Standard Deviation
SWAT	Soil and Water Assessment Tool
SWATCUP	Calibration Uncertainty Program
TDM	Total Dry Matter
TEK	Traditional Ecological Knowledge
TLU	Tropical Livestock Units
TM	Thematic Mapper
TNC	The Nature Conservancy
USDA	United States Department of Agriculture
USGS	United States of Geological Survey
UTM	Universal Travers Marketer

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ABSTRACT

Rice (Oryzae sativa) is one of the leading food crops in the world. It is one of the most important sources of food for the world population. Most wetland areas in the world have been developed for rice-based production systems. Lake Tana area, including the Fogra Flood Plain, has been chosen by the UNESCO-founded 'Man and the Biosphere (MAB)' Programme (1971) as a potential biosphere reserve in Ethiopia. The wetlands of Fogera are affirmed to be under threat by human activities such as unsustainable rice cultivation, sand mining, and natural threats such as the deposition of sediment with different chemicals eroded from upland agriculture areas. The present study was conducted in the Fogera wetland areas of, Amhara National Regional State (ANRS). There was a knowledge gap on the environmental trade-offs of rice intensification and mechanisms to ensure the sustainability of ecosystem functions of the wetland of Fogera Plain. Motivated to fill some of the knowledge, and research gaps, the current study investigated the environmental trade-offs of rice intensification in the Fogera Wetlands and mechanisms of sustaining Lake Tana Biosphere Reserve. The study employed a mixed research approach combining qualitative and quantitative methods of data collection, and analysis. The findings of the study indicated that the majority of the farmers (87%) had not abandoned alternative crops to produce more rice. However, normalized difference vegetation index results indicated that the area cultivated for rice is increasing while the area of other crops is decreasing. Agricultural inputs are used in rice systems but were not used before the introduction of rice. Recession farming activities have also diminished wetland areas. Water flow showed a decrease, whereas Nitrogen and Phosphorus showed an increase with Pearson's correlation values of −0.069 and −0.072, respectively. Flow of water was negatively correlated with Nitrogen (N) and Phosphorous (P) water concentration; whereas N and P contents were positively correlated. Following the expansion of rice cultivation in Fogera wetlands, the study revealed that during the 20 years preceding 2014, the area under rice cultivation increased from 182 ha in 1995 to 9499 ha in 2014 and the amount of rice produce increased from 6701 qt in 1995 to 714,013 in 2015. The size of grazing lands was reduced from 8550ha in 1973 to 126.93 ha in 2021; wetlands from 3114 ha in 1973 to 1245.52ha in 2021; and forests from 1542 ha in 1973 to 1567.93ha in 2021. In the same period, land use/land cover changes showed a negative balance of 40% dry matter, requiring cattle feed to be increasingly supplemented through purchases, or reducing herd number. The study also indicated that the land-use changes were brought at the expense of traditional cattle production systems. Concerning the impact of rice expansion on traditional wetland management in the Fogera floodplain wetlands, the vast majority (87%) of the respondents confirmed that increases in the price of rice encouraged them to shift from cultivating conventional crops to rice farming. Major activities being pursued in the wetlands of the study area do not consider environmental tradeoffs. In conclusion, growth of intensive rice systems has had negative environmental consequences on wetland ecology. Hence, proper management is required to maintain these valuable resources and keep their role in socioeconomic development of the area. Moreover, sense of ownership of wetland resources and their benefit should be revitalized to reduce abusive utilization. Furthermore, there is a need for better education, sustainable tourism and training for green jobs, good leadership, and sustainable development policies and strategies to regulate and manage wetland uses. Above all, rice intensification strategies and other development activities in the study area need to consider environmental tradeoffs which underpins the conservation and wise utilization of wetlands.

Keywords: *Environmental trade-offs, Fogera wetlands, Rice intensification, Lake Tana, biosphere reserve, institutional linkage, common-pool resource management, Soil and water assessment tool, Fogera livestock breed*

CHAPTER ONE

1. INTRODUCTION

1.1. BACKGROUND

Rice (*Oryzae sativa)* belongs to the grass family Oryzeae and is one of the leading food crops in the world. It is one of the most important sources of food for the world population. Around 3 billion people or about 50% of the human population use rice as a food and nutrient source. For instance, China is attested to be the major producer of rice in the world (Zhang and Chen, 2014). It is an important cereal crop in the world, including Africa. Moreover, rice ranks second to wheat in terms of surface area in the world. In terms of importance as a food crop, rice, however, provides more kilocalories per hectare than any other cereal crop. It is asserted that the crop is the only crop grown in submerged flooded soil or paddy fields (Nishiuchi, 2012).

Globally, most of the wetland areas in the world have been developed for rice-based production systems. An increase in rice production is affirmed to lead to changes in production and livelihood strategies (IPMS, 2005). The change in socio-economic conditions, food security pressures, policy support, incentives, and farmers' preferences in response to market demands have given rise to rice cropping patterns that predominates different agro-ecological zones resulting in loss of crop diversification in our world (IPMS, 2005).

With the availability of inputs for intensive agriculture, the cropping system in Punjab state of India (for example) has undergone a paradigm shift, from a much diversified cropping pattern to a mono-cropped one (Velayuthum and Planiappan, 2003). This is affirmed to be underpinned by the expansion of irrigation facilities, high use of chemical fertilizers, and high-yielding variety seed especially in wheat and rice crop cultivation. This system is attested to affect the soil health which creates biotic and abiotic pressure to the soil (Velayuthum and Planniappan, 2003) and human-environment interactions (IPMS, 2005).

Even though rice intensification has increased yields tremendously, it is coupled with increasing pollution and degradation of the natural environment. Moreover, it has profoundly modified the traditional rice-growing environment. It is generally recognized that rice intensification is characterized by disturbances in rice growing ecosystem by mechanization and agrochemicals. For instance, the disappearance of permanent reservoirs of organisms in the vicinity of the fields have decreased species diversity, and the number of edible species traditionally harvested from the rice fields and the traditional agricultural landscape is rapidly disappearing and facing modern social, political, and economic changes (Takeuchi, 2010), which have caused the loss of both biodiversity and ecosystem services (O'Connell, 2003). In other words, this intensification of rice changes the availability of ecosystem services and can have environmental consequences (Karadeniz *et al*., 2009). This brings environmental trade-offs that occur when the provision of one ecosystem service is reduced as a consequence of the increased use of another (Rodriguez *et al.*, 2006; Ramsar, 2008; FAO, 2017). Increasing population pressure associated with the increasing demand for food and economic developments has led to overexploitation and degradation of wetlands throughout the world. These drivers are affirmed to be most severe in developing countries with rapidly growing economies and populations (CSA, 2007). For instance, more than 50% of the world's wetlands have been altered, degraded, or lost in the last 150 years (O'Connell, 2003).

To reverse the aforementioned undesirable situation in the contemporary world, the main priority is to decouple intensification from the environmental degradation caused by some current approaches to intensification. This includes reshaping institutional structures and market signals. Moreover, traditional knowledge about the use of plants, landscape management, and ecological processes becomes integral to organizational and institutional structures that shape the interactions of people with the landscape and regulate the use of resources (Bavikatte and Jonas, 2009). Scholars of sustainable development affirm that wetlands should be managed sustainably to meet human needs for present and future generations (FAO, 2008). In other words, to continuously get the benefits of wetlands for future generations, it is necessary to conserve these resources and reverse ecological changes (Lamsal *et al.*, 2015).

In Ethiopia, wetland performs an important eco-hydrological role in environmental management, though its management suffers from capacity limitations. Moreover, there is little or no awareness of the current status, threats, or values of wetlands, lack of capacity to implement government policies (EPA-Ethiopian Environmental Authority, 2004; Laura, 2009). According to Afework (2005), major threats to wetlands in Ethiopia, include conversion to agriculture like rice farming, overharvesting of the resources, the appearance of invasive species (Water hyacinth), introduction of perennial vegetation, and overgrazing.

In the Lake Tana area of Ethiopia, there are wetlands such as the Fogera floodplain that provided valuable feed stock to Fogera indigenous livestock at large in the previous years because of their high biomass production (Stuip *et al.,* 2018) However, the introduction of rice in the recent years in Fogera floodplain, has encouraged farmers to prefer growing rice instead of other crops and livestock increasingly. This is underpinned by the high yield and market price of rice cultivation compared to other crops (Mesfin *et al.,* 2016).

In general, agriculture faces the great challenge of developing strategies to maintain production while simultaneously reducing environmental impacts. The trade-off between crop production (like rice) and water quality services and ecosystems is one of the most serious issues facing agriculture and interest in achieving win–win outcomes through the management of ecosystem services is growing (Qiu and Turner, 2013). To foster the win–win strategies in wetland agriculture management, more effort is required to quantify the degree to which trade-offs can be mitigated and whether the likelihood of win–win outcomes can be increased (Qiu and Turner, 2013).

Therefore, it needs an effort to adjust to the increasing trends of our population without compromising the integrity of the environment to have a global transition towards sustainable farming (Gomiero *et al.,* 2011). Sadly, most of the previous studies focused on the production and productivity increment of rice crops rather than concerning the wetland environment. Hence, this study was needed to properly assess the environmental trade-offs of rice intensification and forward institutional linkage mechanisms, and planning recommendations to ensure sustainability of the biosphere reserves in the wetlands of the Fogera area.

1.2. STATEMENT OF THE PROBLEM

Ethiopia is rich and diverse in terms of its biodiversity and important habitats and is renowned for its endemic species, both fauna and flora. Fogera is one of the most important areas in the country in terms of its vast wetlands. The Fogera wetland has multiple functions such as fish harvest, pasture for livestock (Fogera Breed exists in this wetland area and is adapted to the wetland system), rice production, and water sources (EWNRA, 2008).

However, the wetlands of Fogera are under threat by human activities such as rice cultivation without due consideration to the sustainability of the wetlands, mining of sand resources, and natural threats such as sedimentation rich in different chemicals from upland agriculture areas through erosion (MoWEM, 1991). As a result, the wetlands of Fogera have faced multiple problems such as serious beach erosion along the coast; full loss of wetlands on the eastern shore of Lake Tana mainly due to heavy siltation and water abstraction; reduction of the discharge of streams and rivers that feed the wetlands, and pollution of rivers and lakes. In addition, there has been vigorous growth of water hyacinth since 2011 in Lake Tana and on Fogera wetlands, though the government and local communities tried to control it in different years, the threat is still there and intensely affecting the wetlands and its resources (Enyew *et at.,* 2020).

With the current trends of increasing agricultural activities in Ethiopia in general and the Fogera wetland in particular, it becomes crucial to protect and conserve our remaining natural ecosystems from non-sustainable forms of human use because this rice cultivation is one of the threats to the wetlands within the area and it results in a loss of biodiversity due to the destruction of the ecosystem (Amhara National Regional State (ANRS), 2015). Perceived reasons leading to wetland degradation include the disruption of these ecosystems by interfering with catchment areas; agricultural intensification (i.e. rice); extensive livestock husbandry; agro-chemical and other pollution; and deforestation.

Various studies were conducted to increase rice yield and market profitability in the Fogera Wetland. For instance, the effect of integrated farmyard manure (FYM) and inorganic nitrogen (N) and phosphorous (P) fertilizers on growth, yield, and terminal moisture stress tolerance of rain-fed (Tilahun *et. al*., 2013); profitability and marketing chain of rice in Fogera Woreda (Astewel 2010); evaluation of the effect of different time and frequency of hand weeding levels on direct seeded rice (Agegnehu *et al*., 2013); and study on the yield and yield components response of rice and to establish the optimum N and P fertilizer levels required for improved grain yield of flooded rice (Heluf and Mulugeta, 2006). However, these studies did not pay attention to the environmental trades-offs and other ecosystem functions of the wetland of Fogera Plain. In other words, there is a knowledge gap regarding the environmental tradeoffs of rice-based agricultural intensification making difficult sustainable use, and conservation of the local wetlands. Hence, this study was motivated to address the aforementioned knowledge gaps by investigating the environmental trade-offs of rice intensification in the wetlands of Fogera areas along the Eastern shore of Lake Tana and providing planning recommendations.

1.3. Objective of the Study

This study was designed to achieve one general objective and five specific objectives.

1.3.1. General Objectives

The general objective of the study is to assess the environmental trade-offs of rice intensification and seek institutional linkage mechanisms needed to ensure the sustainability of the biosphere reserves in the Fogera wetland along the Eastern shore of Lake Tana.

1.3.2. The specific objectives of the study

The specific objectives of the study are:

1 To analyze farm household characteristics and their perceptions of factors influencing the sustainable management of Fogera wetlands;
2 To analyze temporal and spatial changes in cropping patterns, use of inputs, and hydrological alteration on Fogera wetlands;
3 To investigate the impacts of rice cultivation on an indigenous Fogera cattle at the Eastern shore of Lake Tana in the Fegera wetlands;
4 To identify and analyze the environmental tradeoffs of rice intensification and the impact on traditional wetland management in the Fogera wetlands; and
5 To draw institutional linkage mechanisms that facilitate rice intensification by offsetting environmental trade-offs and ensure the long-term sustainability of important biosphere reserves in Fogera wetlands.

1.4. Research Questions

The study answered the following research questions:

1. What are the farm households' characteristics and perceptions of factors influencing the sustainable management of Fogera wetlands?
2. What are the temporal and spatial changes in crop patterns, use of inputs, and hydrological alteration on Fogera wetlands?
3. What effects does rice intensification have on the indigenous Fogera cattle in the Eastern shore of Lake Tana, Fogera wetlands?
4. What are the environmental tradeoffs of rice intensification and the impact on traditional wetland management in the Fogera wetlands;
5. What institutional linkages are required to allow a win-win scenario between rice intensification and environmental trade-offs and ensure the long-term sustainability of important biosphere reserves in the Fogera wetlands?

1.5. Significance of the study

The wetlands will experience significant issues in the future if the current intense rice farming exploitation of floodplains and water resources is adequately managed in the study area. The following is a summary of the local conditions:

- ✓ Given that the Fogera floodplain and wetland are the source of rice crop and other crops and that there are several water sources,
- ✓ Given as a significant source of the indigenous cattle population in the area,
- ✓ Given that the two major rivers in the research area are the sources of sand mineral resources extraction and that the Fogera floodplain is the source of fish supply to major market hubs like Woreta, Bahir Dar, Gondar, and others. Because Lake Tana borders the research area's western edge

To ensure the sustainability of the land and water resources, on which the vast majority of people in the watershed rely for their livelihoods, comprehensive activities are required. To overcome the consequences and maintain the reasonable use and maintainable management of the resources, a scientific study in land and water use management on the Fogera wetlands and the wetland itself is required. Therefore, it is crucial to conduct a comprehensive analysis of the issues using a variety of techniques and tools, as well as with the participation of the key players who face similar planning and governance difficulties, such as government agencies, development partners (such as NGOs), irrigation farmers, educational institutions, and local communities. The use of integrated management plans and a broader conceptualization of the benefits of natural resources, such as lakes, wetlands, pasture areas, bushlands, and sand, are necessary (Romanelli *et al.*, 2011).

In this context, this research is necessary now to identify the issues the Fogera floodplain and its wetlands are experiencing. The outcome might make it easier for policymakers to implement sustainable approaches to managing land and water. The findings of this study can be used to support the initiatives being made by the concerned body. The findings could also be applied to other lakes and associated wetlands, rice intensification, and the management of environmental trade-offs in other parts of the nation to ensure their sustainability. It can also be used a baseline information for other researchers related to this study. It is also significantly important for the local community to use the wetlands and the floodplain if sustainably managed.

1.5. Scope of the Research

The geographic focus of the study was the proposed biosphere reserve areas of Fogera wetlands on the eastern shore of Lake Tana, Amhara National Regional State (ANRS). Specifically, the five wetland kebeles of the Fogera floodplain (Kidest Hana, Wagetera, Nabega, Shaga, and Shina). Thematically, this study focused on assessing the environmental trade-offs of rice intensification and seeking institutional linkage mechanisms needed to ensure the sustainability of the biosphere reserves.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Rice Intensification

Rice has traditionally been cultivated in strongly modified landscapes with rice paddies on hill slopes or lowlands with a water regime. Until the early 20th Century, rice cultivation has permitted a landscape very rich in diversity, especially in macro-invertebrates, fish, and waterfowl (Shimoda, 2007). However, with the intensification of rice practices associated with the ‘green revolution’ in the second half of the 20th Century, fertilizer and pesticide use have increased strongly and have led to a dramatic decrease in rice-field biodiversity (Bambaradeniya, 2003).

According to MEA (2005) summary, intensive rice use of wetlands has altered their ecological character, because the growth of rice crops necessitates reclamation measures such as drainage or tillage. In such wetland areas, biodiversity has often been impacted severely, and large parts may no longer even qualify as wetlands. Where, however, low-intensity rice takes place in wetlands, involving a regime of extensive use without fertilizers or pesticides, the diversity of the wetland landscape may be high, although the species composition and setting differs strongly from that in its pristine situation. This ‘secondary biodiversity’ is often worthy of protection because it includes many rare and characteristic species. The rice intensification of the 20th Century, with its fertilizer and pesticide use, has destroyed many of these values, so that many rice fields are very species-poor (MEA, 2005).

The Practice Path for Rice Sustainable Intensification: - Sustainable intensification practices depend on regional environments, historical developments, and current land-use practices, thus the practice forms are different in different places (Weltin *et al.*, 2018). Research on farmers of sustainable intensification practices focuses on the complementarity analysis between multiple or single rice technologies that measure sustainable intensification practices in different countries and the tradeoff quantifying sustainable intensification practices (Kassie *et al.*, 2015).

A comprehensive set of four sustainable intensification measures at the regional scale, including multiple cropping, no-till, under-irrigation, and abandonment of luxury crops, may save land, water, and soil resources while increasing food security (Firbank *et al.,* 2013). Through similar interventions, sustainable intensification in countries with similar socio-economic characteristics can be promoted (Scherer, 2018). For example, the soil management system designed to protect and increase soil organic matter in Latin America, which increases soil organic matter through the use of carbon-rich coverings, permanent soil coverings, and no-till soil surfaces, has become an important component of crop sustainable intensification (FAO, 2004).

Sustainable intensification of the planting system focuses on studying the resource use efficiency of external inputs and ways to make full use of renewable natural resources within the system to reduce the impact on the environment (Blumenstein *et al.*, 2018;). In the integration of production activities, crop–livestock integration is considered a possible solution to the sustainable intensification of systems (Jonathan *et al.,* 2011). It is important to improve rice productivity through synergies between nutrient flows and material flows of different natures, and to coordinate land use requirements and input-output ratios between farmland and pastures to achieve sustainable intensification of crop-livestock integrated production system for the wetlands (Cortner *et al.,* 2019)

2.2 Input Use

Modern agriculture across the world has seen rapid shifts in technological enhancements, and increased inputs of fertilizers and pesticides that have doubled food production over the past 60 years (Godfray *et al.,* 2010). Society has benefited from these gains through increased food security and reductions in food costs, largely made possible by higher production efficiencies and economies of scale. However, with these benefits, there is ongoing concern about the negative environmental, agronomic, and economic consequences of the intensification of agrochemical use and shifting cropping practices (Pastor *et al.,* 2019).

Unintended environmental impacts of high agrochemical use have led to biodiversity losses, reduced water quality, and increased greenhouse gas emissions. For example, large-scale studies have demonstrated that pesticides were the primary cause for the decline of grassland and farmland birds (Stanton *et al.,* 2018), terrestrial insects (Sánchez-Bayo and Wyckhuys, 2019), and aquatic invertebrates (Beketo *et al.,* 2013). Overuse of fertilizers in recent decades has resulted in elevated nitrogen and phosphorus levels in the environment (Lassaletta *et al.,* 2014), which in turn have polluted surface water (Goyette *et al*., 2016), groundwater (Burow *et al.,* 2010), and coastal zones (Howarth, 2008). In addition, nitrogen-based fertilizers are implicated as a primary source of greenhouse gas emissions in the form of nitrous oxides (Park *et al.*, 2012).

Therefore, considering the ongoing environmental concerns from the continued expansion and intensification of agricultural activities, current agricultural practices require environmentally sustainable solutions, to maintain desired agronomic and ecosystem services (Foley *et al.*, 2011).

Globally, large-scale agrochemical trends in pesticide and fertilizer use have been comprehensively explored (Lassaletta *et al.*, 2014) with a focus on countries where agriculture is a major industry (e.g., United States; or China; Yu *et al.*, 2019). Similarly, recent studies in the United States have projected land cover datasets farther back in time to assess historical land use trends (Arora and Wolter, 2018), to identify socio-political and environmental issues of land use changes within an agro-ecological framework (Spangler *et al.*, 2020), or to identify major drivers of shifting crop diversity (Gosler, 2020). Although Canada is one of the world's largest producers and exporters of major crops such as cereals and oilseeds (FAO, 2018), and agriculture is an important aspect of the country's economy (Sarker *et al.*, 2018), systematic analysis of agrochemical use and associated cropping patterns across the country are limited.

2.3. Impact of Rice Cultivation on an Indigenous cattle population

There seems to be no balance between resource exploitation, conservation, and sustainable utilization that could lead to halting habitat destruction (Getahun *et al*., 2003). This leads to the loss of breeding sites for birds, fish, amphibians, snakes, and other keystone species. For example, the conversion of the Fogera wetland to paddy rice cultivation has been considered a threat to the Fogera cattle breed and the other wetland flora and fauna in the area. Farmers at Fogera wetlands are focusing on the expansion of farmlands for rice cultivation instead of maintaining and scaling up the old tradition of cattle husbandry as a result of which, the forage species of the wetlands are being threatened (IBC, 2009). This has greatly increased the negative impacts, particularly on Fogera cattle, by decreasing the availability of fodder. There is evidence of the cattle changing their feeding habitats to less nutritive and less palatable fodder species, as a kind of coping mechanism, while on the other hand, there is the loss of native forage species diversity.

In general, the major threats to pasture and forage plants is overgrazing and/or over browsing and conversion of pasture land to cropland. As most of the pasture and forage plant species are found in the wild, their threats and trends are similar to those of the forests. The threats on the forage and pasture genetic resources are thereby a threat to the domestic and wild animal genetic resources and other components of the natural resources (Anonymous, 2005).

2.4. Environmental trade-off

Environmental trade-offs occurs when the provision of one ecosystem service is reduced as a consequence of increased use of another (Rodriguez *et al*., 2006). On the other hand, agricultural intensification is defined as an increase in the productivity of existing land and water resources in the production of food and cash crops, livestock, forestry, and aquaculture (Dixon, 2001). Thus, the intensification of rice is promoting the specialization of agro-ecosystems through the decline in landscape heterogeneity, the increased use of chemicals per unit area, and the abandonment of less fertile areas. In combination, these processes have eroded the quantity and quality of habitat for many plants and animals by decreasing the biodiversity and the abundance of species across a hierarchy of trophic levels and spatial scales (Emmerson *et al.,* 2016)

Rice intensification is also a major driver of biodiversity decline since it is dependent on it. Since rice intensification is a monoculture practice, it has only the cultivation of a single crop species in a field. Unlike traditional poly-culture cropping configurations, which mix crop varieties or intersperse crops with trees or domesticated animals, monoculture allows farmers to specialize in crops that have similar growing and maintenance requirements (Gliessman, 2000). The production with intensification has mostly forgotten the potential of agro-ecology as the best approach to move towards the realization of the right to adequate food in its different dimensions: availability, accessibility, adequacy, sustainability, and participation (deSchutter, 2010).

2.5. Institutional Linkages

Effective natural resource management (such as wetlands) and governance require democratic and mutually supportive central and local governance institutions (Lockwood *et al.,* 2010). The role of local institutions such as local government units (kebele and district administrations), both formal and informal local organizations like cooperatives, traditional and culture groups (Mahber, Senbete, and Edir), and NGOs, is becoming more important for successful Common Pool Resource (CPR) management and governance (Ketema, 2013).

Common-pool resource management and governance is a function of the formal and informal institutions that govern and oversee access to and withdrawal of the resource (Ostrom, 1990). These units facilitate knowledge exchange, information flow, and enforcement of formal rules at the grassroots level. However, stakeholders involved in the governing system were not able to understand the local context where local-level governing systems interact with the system to be governed at the operational level. There was also an inadequate understanding of how local communities shape not only the organizations and the resource management and governance outcomes at user level, but even the context and environment in which they operate (Ketema, 2013).

Due to this incongruence, government technical agencies and local-level governance structures have been ineffective in managing and governing CPRs (such as wetlands); it seems they are neither able to replace many of the resource management and governance functions previously provided by indigenous cultural and communal institutions nor complement the informal institutions. There are concerns that some local institutional arrangements are breaking down due to a lack of support from local administrative structures, despite the process of decentralization, and this has major implications for the sustainable use of CPRs (such as wetlands) and food security throughout the region (Maconachie *et al.*, 2008).

The formal rule-making and implementation process is characterized by lengthy, non-participatory, and often poor political commitment of concerned governmental bodies to enforce the rules and regulations at a different level. Local government units, and formal and informal organizations were not consulted in policy planning and governance issues (Ketema, 2013).

2.6. Institutional linkages for sustainable wetlands management

Local institutions, in the context of community-based natural resource management, are widely interpreted as the customs, rules, norms, networks, and patterns of behavior that govern how resources are used and managed (Mazzucato & Niemeijer, 2002). Institutions can be organizations, and vice versa, and in their organizational forms, they represent a means of enforcing accepted norms, rules, and patterns of behavior.

Rasmussen & Meinzen-Dick (1995) suggest that institutions are typically composed of working arrangements that include shared formal or informal rules and understandings relating to resource boundaries, access, and allocation, and conflict resolution; these may also include constitutional rules and external arrangements that delegate decision making to other institutions. They propose local institutions as another ‘missing link’ in development and adaptation at the people–environment interface.

As Boserupian adaptive responses to crises such as resource depletion, they mediate peoples’ relationship with the environment through the networks, knowledge, rules, and social cohesion associated with them (Mazzucato & Niemeijer, 2002), hence they can be facilitators of sustainable natural resource management. A key strength, according to Shivakumar (2003), is their often indigenous nature; local institutions represent ‘homegrown’ solutions to problems based on understandings rooted in the indigenous knowledge and, consequently, are often regarded by local communities as having greater credibility, relevance, and legitimacy than external institutions.

As empirical evidence of the relationship between local institutions and sustainable community-based natural resource management (CBNRM) has emerged (Ostrom, 1990), development practitioners have sought to capitalize on this relationship. In an era when rural development and CBNRM have been dominated by the ideals of participation and civil society, local institutions have been considered potential shortcuts, readymade power structures through which policies can be formed and development initiatives implemented, and models for grassroots development that can be replicated elsewhere (Watson, 2003).

A critical area of debate, however, centers on the development and sustainability of local institutions themselves; whether they can continue to function and support sustainable natural resource management strategies in the context of rapid change and/or increased intervention from external institutions. NGO interventions were perceived as diminishing the existing institutions among their members. Government intervention in the operations of local institutions has also been recognized as a threat to their legitimacy, credibility, and effectiveness (Serra, 2001) has shown in arguing that local institutions become more effective when arrangements in the external environment support them. Certainly, the intervention of external institutions may seem justified if, as Manig (1999) argues, local institutions left to their own devices struggle to adapt to rapid socioeconomic, environmental or political change.

So, managing wetland ecosystems is paramount essential to safeguard wetlands for local communities and environmental functioning and regulation (Hanson *et al.,* 2008). Hence, the management of wetlands is the promotion of these services. However they are at risk mostly due to population pressure worldwide (MEA, 2005). Wetlands have progressively been lost and degraded due to human activities for thousands of years. There is a proper example of wetlands that are already misplaced in Ethiopia (Haromaya Lake) (EWNRA, 2008). They are now recognized as being lost at a rate that is greater than for any other type of ecosystem (McInnes, 2010).

Human impacts on water sources for agricultural, industrial, and settlement are some reasons why wetland ecosystems are degraded at an alarming rate worldwide (Ramsar, 2006). Primary indirect drivers of wetland degradation have been population growth and increasing economic development. Whereas fundamental direct drivers of wetland degradation and loss consist of infrastructure development, agricultural growth (cultivation and overgrazing), water withdrawal, pollution, over-harvesting, and over-exploitation, and the introduction of invasive alien species (MEA, 2005)

In Ethiopia, different stakeholders, local communities, and governmental and non-governmental organizations use wetlands in an uncoordinated manner, and this approach is affecting the vitality of wetlands and speeding up their degradation. As a result wise use of wetlands has not yet been given proper attention and priority (Shewaye, 2008). Lack of complete wetlands policy and implementing regulation coupled with an absence of a group duly empowered to problem and enforce wetland laws and coordinate administration activities is the underlying purpose for the deterioration of wetlands of Ethiopia (Adugna and Bogale, 2015).

The absence of policy and proper institutional arrangements are the key factors limiting affirmative actions against the degradation of Ethiopian wetlands (Legesse, 2007). Wetland management in Ethiopia also suffers from capacity limitations such as a lack of skilled manpower, finance, and technology and a shortage of wetland specialists (Adugna and Bogale, 2015). There is also an awareness problem from the grassroots up to decision-maker level (Shewaye, 2008).

2.7. Common Pool Resources

Common pool resources such as rangelands, forests, fallow fields, and ponds provide an array of social and economic benefits for a wide variety of users in arid or semi-arid lands and wetlands (FAO, 2004), and the products obtained from such resources have been critical elements in the livelihood and survival of these communities, particularly in times of drought. Unlike pure public goods, common pool resources like irrigation systems, fishing grounds, pastures, forests, water or wetlands (Paul *et al.,* 2015).

Common pool resources also refer to natural or people-made resource systems that share two important characteristics: excludability and subtractability (Ostrom, 1990). The first difficulty of exclusion arises from several factors including the cost of fencing the resource and the cost of designing and enforcing property rights to control access to the resource. The second attribute "subtractability" creates rivalry between different users. The resource units (e.g. bundles of firewood or fodder) that one user extracts from a CPR are not available to others. Each user is thus capable of subtracting from the benefits that others derive from CPR. Because of these characteristics, CPRs are potentially subject to over-exploitation, depletion or degradation. A broad challenge in the management of CPRs is how to coordinate the use of the CPRs by individuals as the population grows to prevent overexploitation (Williams, 1998). In line with this, different frameworks and designs were proposed by authors to describe a situation in which CPRs can be managed in a co-ordinated manner.

Ostrom (1990) also found that groups that can organize and govern their behavior successfully are marked by the following principles: (1) group boundaries are clearly defined, (2) rules governing the use of collective goods are well matched to local needs and conditions, (3) most individuals affected by these rules can participate in modifying the rules, (4) the rights of community members to devise their own rules are respected by external authorities, (5) a system for monitoring behavior of group members exists and the members themselves undertake the monitoring, (6) a graduated system of sanctions is used, (7) community members have access to low-cost conflict resolution mechanisms, and (8) Physical attributes; Technology Decision-making arrangements Patterns of interactions Outcomes 6 appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested institutions. These principles facilitate better performance of CPR management over time

In Africa, wetlands regularly occur on communal land and become common resources. Common-pool resources are resources that are competing (i.e. using the resources reduces their availability to other users), but non-excludable (i.e. no single individual can restrict others from accessing these resources) and this often leads to the tragedy of the commons (Costanza *et al.*, 2014) Here individuals need to maximize their benefit from common resources without bearing the full costs of their actions. Instead, these costs are shared among all the users of the resource.

It is difficult, though not impossible, to solve the tragedy of the commons. One solution is collective-choice rules (Ostrom, 2009), where users of wetlands design and enforce their own rules on how to share the resources. However, this solution only works where community members who rely on wetlands are also the ones damaging the wetlands. If, for example, the poor and uneducated depend on wetlands the most, but a different group of wealthy individuals grazes or plow these ecosystems, then a power imbalance exists. Such power dynamics may threaten the sustainable use of common-pool resources (Giller *et al.,* 2008; Reed *et al.,* 2009).

Absent social cohesion, collective action theory argues groups of people will never coalesce into a community that is willing to work together and invest their time to solve a shared problem. For conservation organizations, Olson's theory strongly suggests that a lack of social cohesion within a community is likely to undermine or precludes efforts to promote collective action and successful and durable Community-Based Conservation (CBC) (Hilborn, 2011).

If a group of people has sufficient social cohesion to be willing to cooperate and take collective action to solve a common resource conservation problem, they must then be able to decide how they will manage the resources they care about and enforce these decisions (Gibson *et al*., 2000)

2.8. Wetland Degradation

There are extensive wetland systems throughout Ethiopia which owns more than 58 different types of wetlands that provide enormous socio-economic and environmental values such as hydrological and ecological functions, which support various economic activities, life support systems, and human welfare (Hagos *et al.,* 2014). This includes groundwater recharge, flood control, nutrient cycling, erosion control and sediment traps, climate regulation, habitats for migratory wildlife, and pest control (Dugan, 1990). The direct use also includes fishing, fiber production, water supply, recreational opportunities, and increase tourism.

Despite all those and other indispensable values, these wetlands are under severe pressure and degradation. Due to improper extraction of uses and misconceptions forwarded to wetlands, the health of the wetlands is continuously decreasing from time to time that in doubt of their existence shortly (Hagos *et al.,* 2014). They said also that traditional and modern agricultural expansions, continuous land degradations, urbanizations and industrializations, lack of policies and institutional arrangements, lack of capacities, and natural and ecological problems are the most dominant challenging factors of wetlands in the country.

In addition, another important reason for their vulnerability is the fact that they are dynamic systems undergoing continual change. As a result, many wetlands are temporary features that disappear, reappear, and re-create themselves over time (Barbier *et al.,* 1997). Matthew *et al.,* (2006) summarized stating it 'most acute trade-off between environmental protection and development resulted from dynamism and complexity of wetlands'. Though wetlands face several threats from natural factors globally, most of the threats have resulted from directly or indirect human interaction with the wetlands.

Therefore, Dugan (1990) claims that 65% of wetland disturbances are of human origin, while the remainder have natural origins. Out of these human-origin disturbances, 73% are thought to result from direct human actions, while the remaining 27% are believed to come from indirect sources. Ethiopian wetlands could not be different from this truth. Like in other African countries, most of the threats in Ethiopian wetlands are the result of the direct and/ or indirect unhealthy human interactions. Natural factors are also coming important influencing factors (Dugan, 1990).

Improper agricultural practices and expansions in debate about the future of wetlands tends to divide between those seeking to develop these areas for agricultural production (crop producers and livestock rarer) and those who believe that wetlands must be preserved as much as possible in a stable state to maintain their ecological contributions to the ecological system (Ecologists) (Dixon and Wood, 2007). The perception of the premier extends up to assuming wetlands as wastelands. In concentrating on the first big argument, it is a very serious issue, especially in developing countries that dominate the balance of debate. Accordingly, converting to agricultural land is better than keeping the wetlands and gaining their value. The flat topography, fertile soil, reliable provision of water at the dry season, etc. of wetlands is some of the attractive factors.

In Ethiopia, the debate is between consequences on one side and the government and the farmers on the other side. The government and farmers need converting the wetlands to gain more products at a time. The highlands of south west Ethiopia and the swamps of Awash Valley are good examples of where the government and farmers are engaged in producing more than seeing sustainable use of the resources (Dixon and Wood, 2007).

Complete conversion and modification of wetlands to cultivated land, improper citation of large-scale farming systems, improper farming methods and poor tillage systems, and planting more water requiring perennial crops and plants are some of the agriculture-related threats of Ethiopian wetlands (Hagos *et al.,* 2014).

The amount of solid and liquid wastes generated by different sources is increasing in size and composition a problem for Ethiopian wetlands. The illegal settlements in and around wetlands also affect the health and size of the wetlands significantly. Most of the problems from urban to wetlands in Ethiopia are related to the absence of systems that collect and manage solid and liquid wastes (Abebe and Geheb, 2003)

2.9. Consequences of Wetland Loss and Degradation in Ethiopia

Alterations of the hydrological regime of wetlands have significant physical, chemical, and biological effects that can have significant ecological and socio-economic implications at wider scale. On the other hand, the presence of water is the main obstacle to humans when wetlands have to be transformed into another form of land use (Roggeri, 1995).

The consequences of wetland loss and degradation in Ethiopia are enormous and directly affect the livelihood base of rural communities. The change of wetlands has created numerous problems including the decrease and extinction of wild flora and fauna, loss of natural soil nutrients, and water reservoirs, and their subsequent benefits. They have affected various traditional occupations, socioeconomic conditions, and cultural activities (Kumsa, 2015).

Wetland conversion often results in water depletion, the displacement of populations, the destruction of traditional production systems, habitat degradation, salinization, increase of waterborne diseases, and other adverse ecological impacts, and the process of intensification is typically driven by increased use of fertilizers and other chemical inputs, which have been connected to negative environmental outcomes including air and water pollution (Tang *et al.,* 2014), reduced soil fertility (Tsiafouli *et al.*, 2015), destruction of biodiversity (Karp *et al.*, 2012) and increased propagation of disease (Jonsson *et al.*, 2012; Pulliam *et al.*, 2012). Wetland-dependent communities in different parts of Ethiopia survive by virtue of wetland resources such as fisheries, dry season food crops, raw materials for construction, water, feed for animals, medicinal plants, income from the sale of the products including handicrafts, etc. Thus at the community level, the significance of wetlands in poverty reduction and ensuring food security is immense. Wetlands stand first when communities consider their problems of the dry season when the shortage of water and forage threatens the lives of their livestock, a major asset next to land in agricultural areas and may be asset number one in pastoral communities (Kumsa, 2015).

But losses of communal resources collected from the wetlands, water, dry season pasture, and declining of food crop production are a few to mention (Dixon and Wood, 2003). Pollution of habitat and overfishing of selected species is among the biggest concerns in the Ethiopian lakes. Wassie *et al.,* (2012) noted that selective fishing in Lake Tana caused a 75% decline in Labeobarbus species during the 1990s. Excessive water abstraction from wetlands and erosion and sedimentation are other serious threats. Ghermandi *et al.*, (2008) found out excessive abstraction of water from Lake Alemaya, South-eastern Ethiopia caused complete drying up of the lake by the year 2004, 12 years earlier than the predicted time. Recently, there have been increasing treats to the valley bottom wetlands of South-west Ethiopia which mainly arose from expansion of drainage and cultivation (Dixon and Wood, 2013).

The complete drainage of wetlands in Illubabor Zones, southwest Ethiopia has led to several ecological and economic problems. Some of these are immediate and linked to drainage, such as the scarcity of thatching reeds, vegetation change, lowered water tables, reduced accessibility, and unsafe water (Wood, 1996). This unsafe water may lead to even greater issues such as ill health among the entire family, which in turn affects farming and other domestic and economic activities, reducing food security and lowering economic well-being (Wood, 2003).

Other problems are more complex and long-term, such as declining agricultural productivity, reduced availability of land for ‘hungry season’ crops, increased fluctuations in stream flow, reduced water quality, and downstream hydrological impacts. Loss of wetlands may also decrease biodiversity such as birds and other wildlife (Idris *et al.*, 2001).

Wetland loss also aggravates climatic disturbances by increasing carbon buildup in the atmosphere. As Ethiopia is prone to desertification and recurrent drought, the effects of wetland loss could be more visible in complicating the situation locally. It can also affect the hydrological cycle or rainfall patterns. Rivers and streams may lose their strength. This will create a shortage of water and narrow opportunities for irrigation-based agriculture. Wetlands play a vital role in the carbon cycle and wetland loss may have impacts that encourage global warming and climate change (Shewaye, 2008).

2.10. Sustainable Use of Wetlands

The Ramsar Convention defined ‘wise use’ as follows: It is sustainable utilization for the benefit of mankind in a way harmonious with the maintenance of the natural properties of the ecosystem (Davis, 1993). The term ‘wise use’ compresses the need to safeguard the integrity of wetlands while at the same time providing sustenance to the natural and human communities. It involves the maintenance of their ecological character as a basis not only for nature conservation but for sustainable development (Abebe and Geheb, 2003).

The wise use of wetlands is impractical if the people who make use of them are not involved in one way or another. The involvement of such people and knowledge of their values is the basis for the implementation of wise use strategies (Abebe and Geheb, 2003). If many of the causes of wetland degradation and loss are of socio-economic origin, then social and economic factors need to form the crux of wise use programs. In particular, indigenous populations should be the beneficiaries of the improved management of wetland sites (Davis, 1993). The wise use of wetlands is a complex concept to implement and requires the support of national programs addressing several factors including information, policy, research, awareness, management, and institution building (Dugan, 1990).

Use of Organic Inputs Organic inputs used in soil fertility management commonly consists of livestock manures (farmyard manure), crop residues, woodland litter, household organic refuse, composted plant materials (compost), and any plant biomass harvested from within or outside the farm environment for purposes of improving soil productivity. In urban and peri-urban areas, organic inputs can also be made up of industrial organic waste and sewage sludge. Organic resources have multiple functions in soil, ranging from their influence on nutrient availability to modification of the soil environment in which plants grow (Owethu and Buschke, 2019)

Mono cropping has led to soil erosion, poor soil fertility, and finally decline in crop productivity. It leaves the same nutrients from the earth and leaves soil weak and unable to support healthy plant growth. This may farmers to be forced to use chemical fertilizers to encourage plant growth and fruit production. These fertilizers, in turn, disrupt the natural makeup of the soil and contribute further to nutrient depletion. Mono crops also provide a friendly home for pests that happen to like that crop, since it shows up reliably, every spring. Organic Farming, the Alternative Approach Monoculture problems can be avoided altogether if organic farming methods are employed. Maintaining soil health is the central tenet of organic farming (Tegegn and Eshetu, 2023).

2.11 Rice production in Ethiopia

Rice cultivation in Ethiopia is more recent history than its utilization as a food crop. It is among the important cereal crops grown in different parts of the country as food crops (Astewel, 2010). Some evidence show that cultivation of rice in Ethiopia was first started at the Fogera and Gambella plains in the early 1970s. Currently, the Fogera, Gambella, Metema, and Pawe plains located in the northern, northwestern, and western regions are developing into major rice-producing areas in Ethiopia (Mulugeta Seyoum, 2000). Bull (1988) estimated that about 3.5 million hectares of vertisols is found in the Amhara region, which remains waterlogged for most of the year, and possible to produce food crops in these soils through better water management (drainage) and use of water-loving crops such as rice.

At the Fogera floodplain, rice plays an important role in relaxing the problem of food insecurity of the farming community. It offers a variety of uses to the farming community. It is used in the preparation of local foods in addition to local beverages and katikalla either alone or mixed with other cereal grains (Mulugeta and Heluf, 2005). Moreover, rice could also be considered as one of the best and cheapest alternative technologies available to farmers for efficient utilization of natural resources, such as land and water, under swampy and flooded environments (Mulugeta and Heluf, 2005). Because of its wider adoption from farmers' social, economic, and environmental perspectives, rice production at the Fogera Plain is expanding rapidly from year to year. As a result, for instance, between 1994 and 2000, the land cultivated with rice increased from 65 to 4,174 ha. In addition, according to the report of NRRDS (2008), in the Amhara regional state, the estimated area and production of rice was also 52985 ha and 140,235 tonnes, respectively.

However, the production and productivity of the crop under farmers' field conditions is low (about 2600 kg of rice grain ha^{-1} on average) compared to its yield levels under farmers' conditions in other parts of the world. Yet, improvement of its production has not been possible due to several soil-plant-management-related factors. Low soil fertility and inadequate nutrient management are among the major factors determining its yield level (Mulugeta and Heluf, 2005).

Generally, rice is an important crop throughout the world and Ethiopia in general and Fogera Woreda in particular. According to Heluf and Mulugeta (2000), increasing rice yield in the Fogera floodplain was also possible by combining the use of Nitrogen and Phosphorous fertilizers. Hence, since recently, artificial inputs have been used to increase the productivity of rice in the area. In addition, all or some of the factors can lead the farmers' attention to produce more crops regardless of the negative effects on the environmental resources of the wetland such as physical, economic, personal, crop profiles, and availability of resources are mentioned as main factors (Laura, 2009). However, various studies show that artificial input supplied through chemical sources, enhances yield initially, and lead to unsustainable productivity over the years (Mahajan *et al*., 2008). Therefore, continuous use of inorganic fertilizers leads to deterioration of the biodiversity of the wetland of the area (Mahajan *et al*., 2008).

Therefore, the overall pattern of future agro-environmental impacts are one of trade-offs between increased agricultural production and reduced pressures on the environment. Intensification of crop production on existing cropland reduces the pressure to deforest but tends to increase water pollution by fertilizers and pesticides. Similarly, the change from traditional mixed and extensive systems to more intensive systems has probably had a positive effect in improving land- and water-use efficiency but negative effects on water pollution from poorly managed manure storage (Hoving *et al.*, 2014).

2.12. Agriculture and Biodiversity

Agricultural systems contain several dimensions of biodiversity. For instance, "Planned" biodiversity is one of the best dimensions of agricultural systems. It refers to the diversity of crops and animals chosen by a farmer for production, while “associated” biodiversity includes the micro-organisms, insects, birds, and other wildlife that both depend upon and help maintain agro-ecosystems (MEA, 2005),

By reducing planned biodiversity to include only one crop, monoculture affects the composition and abundance of associated biodiversity. For example, the balance of plant pests and their natural enemies that may exist in poly-culture fields can be disrupted in monoculture systems, which provide habitat for a narrower range of insects (Matson *et al.*, 1997). Populations of bees, flies, moths, bats, and birds, which provide important pollinating and pest pressure services to crops, also tend to be lower in monocultures than in fields containing diverse forage and nesting sites (MEA, 2005). As a result of reduced biodiversity, monoculture systems are more susceptible than poly-cultures to insect infestation and plant viruses. For example, found evidence of reduced rice yields throughout Southeast Asia due to increased pest populations in monoculture rice systems (Pingali & Rosegrant, 1994).

To manage pests in monoculture fields, farmers must apply chemical pesticides, leading to negative impacts on water quality, wildlife populations, non-target organisms, and human health (MEA, 2005). On the other hand, rice in many parts of the world has been farmed for centuries in a sustainable way in landscapes with high biodiversity because it keeps its traditional way of farming system (Sonja, 2012). Rice fields are traditionally characterized by a rich flora and fauna, with aquatic plants and invertebrates in the aqueous phase of the system and (semi-) terrestrial species in the vegetation. So, fish, amphibians, reptiles, and birds are abundant and rich in species. In addition, there are many examples of combined cultures of rice production and fishing (Sonja, 2012: Fig.2.1).

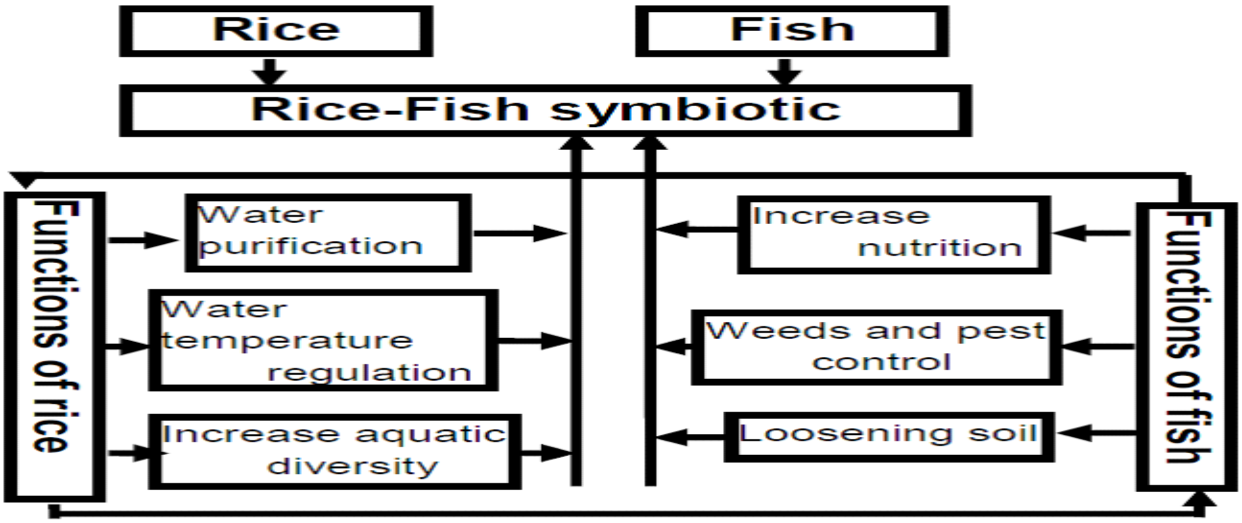

Fig. 2.1 Functions of Rice Fish Cultivation (RFC) SystemFig

Source: Adopted from CNACH & IGSNRR (2011)

Therefore, to keep the wetlands or floodplain from different pollutants, it needs good planning that helps for the protection of wetland degradation. Hence, it is possible to protect the entrances of pollutants to the wetlands through a buffer. The wetland buffer is a commonly-recognized component of the wetland catchment. It can be defined as the natural terrestrial vegetation upslope of the wetland-dependent vegetation (Davies and Lane, 1995) or more simply as a 'zone' around the wetland that extends outwards from the wetland to human land use (Castelle *et al.*, 1994).

The width of the buffer required to achieve the functions outlined above is dependent on several factors. These include slope of the land and how significant it is for sediment erosion, the type and amount of vegetation and how effective it is in stabilizing the ground, soil types and how far the surface water infiltrates the soil, and the requirements of the biota that inhabit the buffer (Davies and Lane, 1995). In addition, the intensity of the land use adjacent to the buffer may also be a factor in the determination of effective buffer widths (Castelle *et al.*, 1992). So, buffer widths suggested for various buffer functions are included in (Table 2.1)

Table 2.1 Buffer widths suggested for various buffer functions

Purpose	Buffer width needed to perform function (m)
Protection of inflowing surface water quality (sediment	As little as 6 m for low overland

and nutrient trapping)	flow rates
Maintenance of ecological processes and major food-webs	20-50
Protection of inflowing groundwater quality	250
Sediment and phosphorous removal	9 - > 30
Nitrogen removal	30 - > 50
Wildlife protection	30- > 90

Vegetated buffers shown to be able to attenuate nutrients and sediment, as well as contaminants, range from 2 m in width to over 100 m, and results are highly variable between and even within studies (Lowrance, 2002). While buffers in the 2 m to 9 m range have been shown to attenuate some sediment and phosphorus, buffers in the 9 m to 30 m range tend to demonstrate more consistent and complete attenuation, and many authors agree that, in general, effective water quality functions are best performed by buffers in the 30 m width range (Dillaha, 1989).

Unless the footprints of agriculture are carefully reduced through improved agro-ecological management, both agricultural systems and remaining natural ecosystems will suffer further degradation, thus increasing the proportion of the world's species threatened with extinction and further limiting the ecosystem services provided by agriculture for humankind (Perfecto *et al*., 2009).

2.13. Sustaining Biosphere Reserve

Biosphere Reserve (BR) is an international designation by UNESCO for representative parts of natural and cultural landscapes extending over large areas of terrestrial or coastal/marine ecosystems or a combination thereof. BRs are designated to deal with one of the most important questions of reconciling the conservation of biodiversity, the quest for economic and social development, and maintenance of associated cultural values (Pandurangan, 2023). Therefore, BRs are thus special environments for both people and nature and are living examples of how human beings and nature can co-exist while respecting each other's needs.

The concept of Biosphere Reserves was introduced in 1975 (Jaisankar, 2018) by UNESCO in response to the need for the conservation of biodiversity whilst ensuring its sustainable use. It is to preserve genetic diversity in representative ecosystems by protecting wild animals, the traditional lifestyle of inhabitants, and domesticated plant/animal genetic resources (Jaisankar, 2018).

Biosphere reserves are privileged places to understand how to sustainably manage and govern social-ecological systems (Ferreira *et al.*, 2018) and to advance sustainability science (UNESCO, 2015: Reed, 2019). Biosphere reserves are the means of implementation of the United Nations Educational, Scientific and Cultural Organization (UNESCO) Man and Biosphere (MAB) Program (UNESCO, 2015). According to the Statutory Framework (Grandia, 2009) and the most recent MAB Strategy (UNESCO, 2015), biosphere reserves have four main goals: (1) the conservation of biodiversity, sustainable use of natural resources, and restoration of ecosystem services; (2) sustainable human and economic development, and promotion of healthy and equitable societies; (3) logistic support to research and environmental education and the facilitation of sustainability science and education for sustainable development; and (4) contribution to the mitigation and adaptation to climate change.

2.14. Organic Farming

Organic farming can be defined as farming that does not use fertilizers, synthetic pesticides, or synthetic compounds. Instead, promote sustainable agricultural practices through the use of natural fertilizers, biological pest control from animal and plant waste, organic fertilizers, and more (Zhang, 2022). Another definition by the International Federation of Organic Agriculture Movements (IFOAM) 'organic farming' is the agricultural process that utilizes ecologically based bio-fertilizers and pest controls abstracted substantially from plant and animal waste and organic manure (Nedumaran *et al.*, 2020). Organic farming uses almost exclusively biological and natural materials and processes to produce food. The practice aims to protect human health and conserve, maintain, or enhance natural resources, to preserve the quality of the environment for future generations while being economically sustainable (Escobar and Hue, 2007). Its management relies on developing biological diversity in the field to disrupt habitat for pest organisms, and the purposeful maintenance and replenishment of soil fertility (Singh, 2021). According to Singh (2021), organic farmers are not allowed to use synthetic pesticides or fertilizers.

For instance, various studies contend that excessive conventional farming can contribute to contamination of the entire food chain, calling for the adoption of safer and better foods produced through eco-friendly practices that are highly authentic, thus the need for 'organic farming' (Roshan and Harisha, 2023)). Agricultural development policy for developing countries needs to focus on increasing the productivity of the land under cultivation, with lower costs, and higher efficiency of products with little or no damage to both humans and the environment (Nedumaran *et al.,* 2020)

2.15. Theoretical Framework

A novel conceptual framework for evaluating sustainable rice intensification routes that include wetlands, rice farming, livestock, and the environment is presented in a theoretical framework for sustainable intensification. Three interesting theoretical frameworks can illustrate the problem of the influence of intensification on the environment. Discussion of the theoretical literature serves to establish a conceptual framework that will loosely direct the remaining parts. Increased usage of production inputs like fertilizer, insecticide, herbicide, and high-yield crop types are frequently used to describe agricultural intensification. Some of these inputs which have an immediate environmental impact on the site and nearby areas.

The extent of these direct environmental effects on water quality or quantity, air quality, or biodiversity, for instance, is essentially a matter of empirical review; their theoretical effects are frequently obviously detrimental.

A more argumentative issue is whether intensification increases or decreases the usage of land, another crucial agricultural input. The connections between intensification and land use have been studied using a variety of economic models and policies. Most crucially, according to Ceddia *et al*., (2014) Borlaug's premise, boosting agricultural output per unit area will lessen the need for agricultural expansion, lessening pressure on nearby land, and result in less land being turned from its natural form for agricultural production.

Contradicting an alternate theory to Borlaug's hypothesis is Jevon's paradox, which states that when an input (such as agricultural land) becomes more productive, the general consumption of that input increases rather than decreases (Ceddia *et al.*, 2014). Increased yields in the event of agricultural intensification lead to a rise in profitability, which raises demand for agricultural land. When the scale effect is more significant than the efficiency gains supporting Borlaug's hypothesis, the paradox can become apparent. Villoria *et al.*, (2014) note in their review of the effects of agricultural technological progress on deforestation that empirical evidence for Jevon's paradox is much weaker than what the literature seems to accept.

The characteristics that distinguish results that are compatible with one postulated picture of the universe from the other can be explained by a theoretical framework that takes into account both Jevon's paradox (in which an increase in the productivity of one input (e.g., agricultural land) leads to increased, rather than decreased, overall use of that input (Ceddia *et al.,* 2014)) and Borlaug's hypothesis (suggests that increasing agricultural productivity per unit area will decrease the need for agricultural expansion, reducing pressure on adjacent land and resulting in less land being converted from a natural state for agricultural production). For instance, Jevon's dilemma is more pertinent for markets with price elastic demand, whereas Borlaug's hypothesis is frequently connected with a constant demand for food (Hertel *et al.,* 2012).

Whatever the case, changing land use frequently has extra negative effects on the ecosystem. In other words, by its impact on land use, intensification might indirectly affect other outcomes. For instance, according to the IPCC's (2019) estimate, agriculture, forestry, and other land uses account for 23% of all human GHG emissions. An increase in acreage used for agricultural production may mechanically result in more harm to water or air quality, for example, if it employs both land and ecologically hazardous inputs, like fertilizers or pesticides.

In addition to Borlaug's hypothesis and Jevon's paradox, Policies that support agricultural intensification may influence the environment, and the results may differ depending on the specific policy tool used. The environmental effects of various intensification programs are demonstrated (e.g., Paul *et al.*, 2018; VanWey *et al.*, 2013) and depend on the type of policy instrument used. To encourage agricultural intensification and reduce the possible negative effects, many policy strategies have been taken into consideration. Maertens *et al.,* (2006), for instance, demonstrate that while adoption of hand tractors (a labor-saving technology) increased pressure on forests, access to improved irrigation systems for paddy rice farming in Indonesia reduced agricultural expansion along forest margins.

Policymakers emphasized the significance of governance in reducing the impact of intensification on environmental outcomes rather than a single policy tool. For instance, Ceddia *et al.*, (2014) realize that when comprehensive governance ratings are high, intensification results in a spatial expansion of agriculture. This implies that ecologically conscious governance may be able to mitigate the detrimental consequences of intensification.

Therefore, Intensification will typically have negative effects on the environment due to habitat loss, GHG emissions, and changes to the local hydrology and ecosystems to the extent that it results in an increase of the land under production. Hence, based on the above theoretical framework, this study tried to formulate the following conceptual framework (Fig. 2.2). The figure is the schematic presentation of the focus of the study. The focus of the study is the intensification of rice crops and the environmental trade-off in the wetland (floodplain) of Fogera area.

The concept explaining that rice intensification has both positive and negative directions similar to Jevon's paradox, which states that when an input (such as agricultural land) becomes more productive, the general consumption of that input increases rather than decreases. The idea of this theory is best described Fogeran case. The positive direction of this study is increasing rice yield and the negative direction is the pollution and hydrological alteration of the study area and disruption of biodiversity (environmental trade-off) which needs a sustainable rice intensification mechanism for the study area.

2.16. Conceptual framework

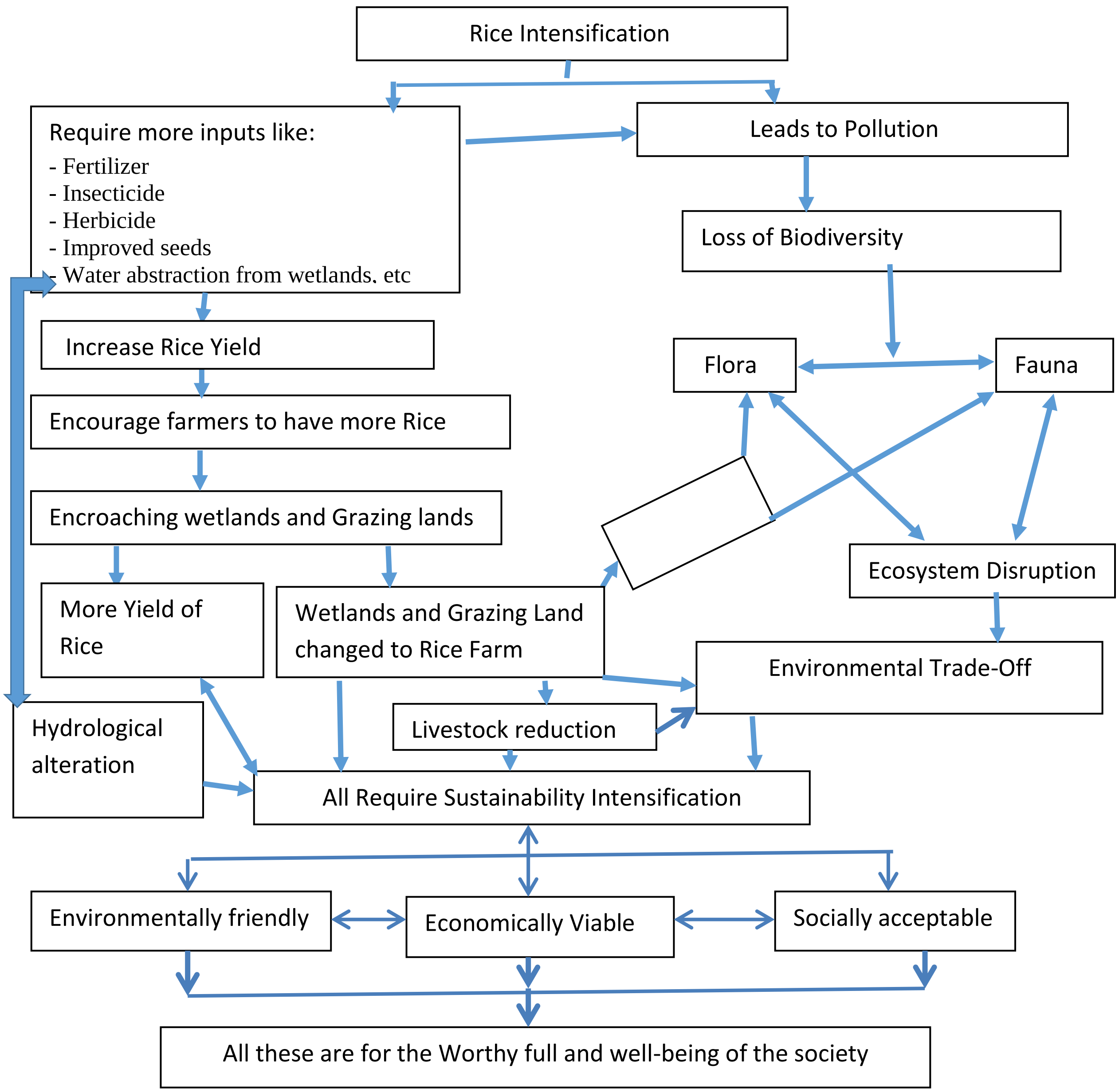

Fig. 2.2 Conceptual Framework of rice intensification and environmental trade-offs

The conceptual framework of rice intensification and environmental trade-off has an overall role for guiding this research. The rice intensification requires more inputs like fertilizer, water, improved seed, land, insecticide, herbicide, etc. to increase rice yield. Even though these different inputs are very important for maximizing rice yield, it has its negative implication. Its negative implications could be an increasing of pollution that leads to biodiversity loss which brings the environmental trade-offs. Therefore, summarizing the conceptual framework leads the study of sustainable rice intensification for the worth full and well-being the society.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. The Study Area Description

The study was conducted in Fogera Wetlands, Fogera Woreda, Amhara National Regional State. Fogera Woreda is situated at 11°46' to 11°59' latitude North and 37° 33' to 37° 52' longitudes East and the altitude of the Woreda ranges from 1,774 to 2,410 meters above sea level and 14 years mean annual rainfall and temperature is indicated in (Fig. 3.2) with long rain from June to September. LiboKemkem Woreda borders the Woreda in the North, Dera Woreda in the South, Lake Tana in the West, and Farta Woreda in the East (Fig. 3.1).

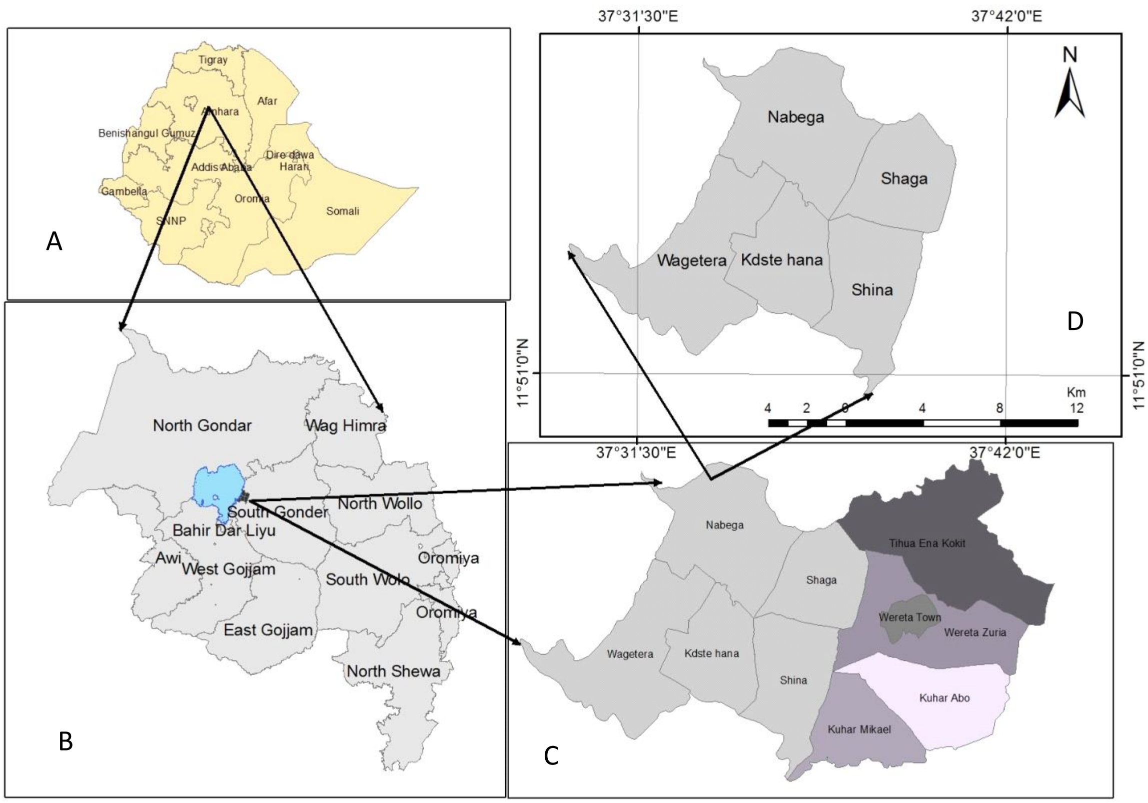

Fig 3.1 Map of the study area (source Ethiopian Mapping Agency

A = the map of Ethiopia with Regional map of Amahara
B = shows Amhara Region and zones
C = Fogera Woreda BR kebeles and
D = Study kebeles

The agroecology is predominantly classified as Woina-Dega. Woreta is the capital of the Woreda and is found 625 km from Addis Ababa and 55 km from the Regional capital, Bahir Dar.

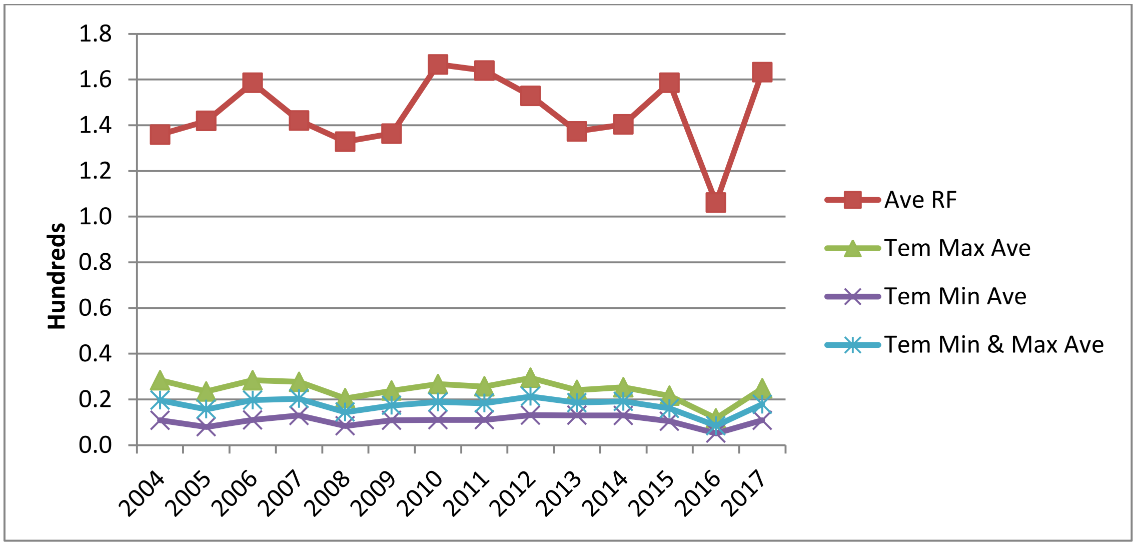

Fig 3.2 Fourteen years average rainfall and Temperature graph of the stations around Fogera

Source North West Region Meteorology Agency (Bahir Dar)

3.1.1. Human Population of the Woreda

The general total population of the Woreda is 53972 in 2007 census and 300,473 in 2022 projection (Table 3.1) 270.3/km² Population Density in the projected 2022and 1.8% Annual Population Change 2007 → 2022

Table 3.1 Population Size of FogeraWeredas as of July 2021

	Census 2007			Projection 2022		
Fogera Woreda	Male	Fmale	Total	Male	Femal	Total
	27315	26657	53972	152,829	147,644	300,473

3.1.1. Livestock Population

About the livestock population of the Fogera Woreda (District) Agricultural Office 2018 report the current livestock population of the district is estimated at 182729 cattle, 15575 sheep, 25956 goats, 3 horses, 13782 donkeys, 568 mules, and 379067 poultry.

3.1.2. Topography of the Study Area

The total land area of the Woreda is 117405 ha. Flat land accounts for 76%, Mountain and hills 11%, and valley bottom 13%. Average land holding is about 1.4 hectares with a minimum and maximum hectare of 0.5 and 3.0 hectares, respectively.

3.1.3. Infrastructure Development

Woreta and Alember are two major towns in the Woreda. Both towns have supplies of potable water and electric power. Both towns have also telephone service. The Woreda has 17 km of asphalt road that crosses the town. There are also 38 km of weather roads and 67 km of dry weather roads. The Woreda is divided into 25 rural Peasant Associations (PAS) and 5 urban kebeles.

Fogera Woreda is one of the surplus crop-producing areas and has a good potential for rice production, which is of course the dominant crop in Fogera wetland. The area gets much of the flood water that accumulates around Lake Tana and the two big rivers, i.e., Rib and Gumara. The rivers bring eroded soil from uphill and deposit on the lowland plain. The soil seems relatively deep and fertile. In the study area, rice is planted at lower slopes where the water table moves to the surface for a substantial period during the cropping season. In addition, rice is irrigated with water, which is diverted from the streams at the upper part of a drainage system. However, the irrigated water is usually not substantial.

In Fogera and the nearby Woredas water supply to rice plants is principally provided by rainfall, run-off water, and under-ground water. Farmers constructed small bunds which are usually used for rain-fed rice production. The bunds serve to retain flood water, as well as rainwater, which falls during the growing season and we also can see the land use cover in (Table 3.2) (IPMS, 2005; Abaye, 2007).

Table 3.2 Land use pattern of Fogera Woreda

Land use	Area coverage/ha	coverage in %
Land planted with annual crops	51472	44
Grazing Land	26999	24
Area covered with water (wetland)	25052	21.4

Infrastructure including settlement	7075	6
Un productive land (hills)	4375	3.70
Forest land	2190	1.80
Perennial crops	2190	0.20
Total	117414	100

Fig. 3.3, 3.4, 3.5, and 3.6 indicate that the Rib watershed includes the Ribb sub-watershed and the study area of the Fogera floodplain of the wetlands, the land use and land cover of the map of the Ribb watershed including the study area, the soil map of the Ribb watershed including the study area, and the slop map of the Ribb watershed including the study area, respectively, and all the maps are used as inputs for the SWAT model.

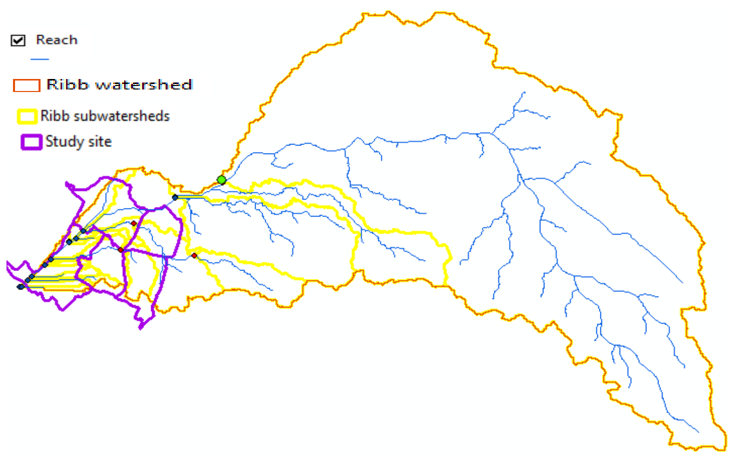

Fig 3.3 The Map of the Ribb watershed and the study area

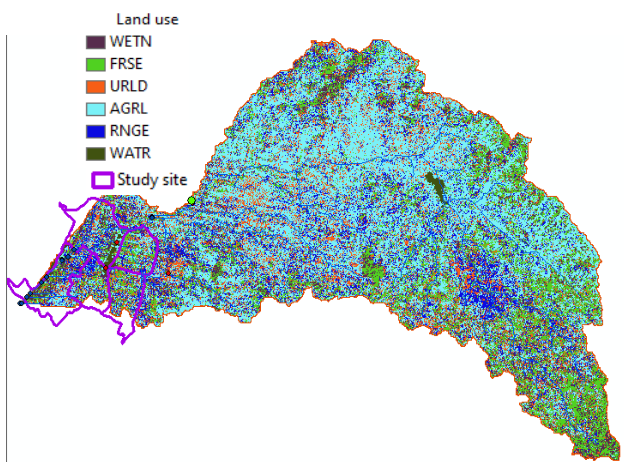

Fig 3.4 Land use/cover map of Rib watershed including the study area

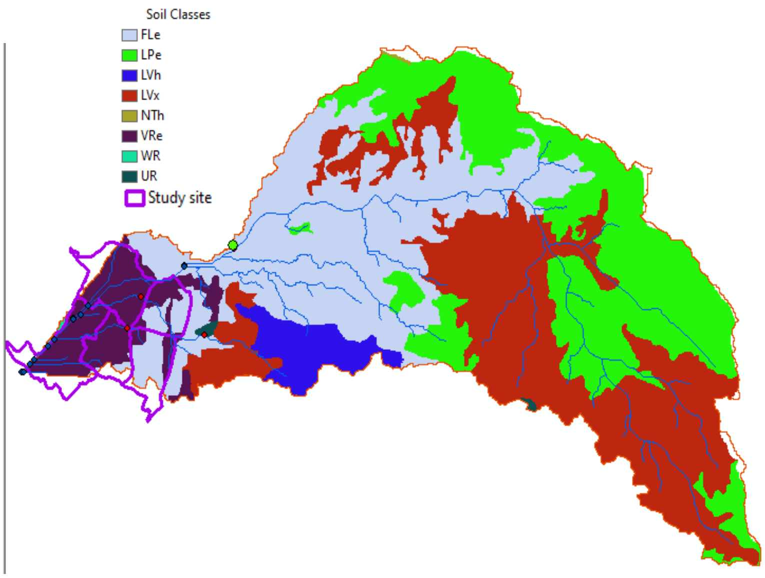

Fig 3.5 Soil map of Rib watershed including the study area

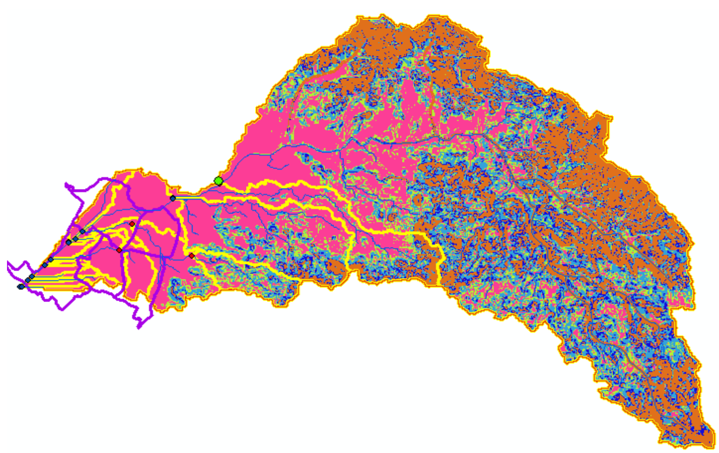

Fig 3.6 Slope map of the Ribb watershed including the study area

3.2. Research Design and Approach

About research design of the study, the study employed a mixed research design for its socio-economic component. Accordingly, the descriptive research design was employed for its quantitative research component guided by a household survey. On the other hand, the study employed an exploratory research design for its qualitative component guided by focus group discussion, key informant interviews, and personal observation.

About research approach adopted in the study, the study adopted a mixed research approach. Accordingly, the quantitative research approach was adopted for its quantitative research component, and the qualitative research approach was adopted for its qualitative component. In other words, quantitative methods and tools were employed for quantitative data collection and analysis. Similarly, qualitative methods and tools were employed for qualitative data collection and analysis.

3.3. Sampling and data collection methods

The Lake Tana Biosphere Reserve (BR) region consists of 10 Woredas and 137 kebeles (the smallest administrative unit). Expert interviews were conducted during initial field visits to understand the situation of the wetlands of the study area and the impacts of human activities on the indigenous cattle population through rice cultivation to get appropriate sample sites and framing of data collection instruments.

Based on a preliminary assessment during a field visit, and subject matter expert interviews (Agricultural and Environment Protection) of the BR sites, it was found that the wetlands are highly vulnerable to environmental tradeoffs (encroachment of wetland resources). Expansion of intensive rice cultivation into what have been historically uncultivated wetlands, forested lands, and grazing lands and different development activities, such as irresponsible fishing, sand extraction, and illegal recession farming.

Therefore, one hypothesis was that conversion of the wetland into rice cultivation places pressure on these traditional land-use areas, and in particular grazing lands, which has negative implications for the sustainability of traditional livestock-based farming systems as well as indigenous Fogera cattle breeds.

For this study, five kebeles were selected purposively for household surveys (Table 3.3). The purpose for selecting the five kebeles was that they were located in the Fogera wetlands representing the most affected areas by the issues under investigation. In other words, the kebeles that are included in the BR were identified as rice-producing wetlands and close to Lake Tana and the floodplain. The number of households chosen for the household survey in each kebele was equal to approximately 3.8% of the total number of households (Table 3.3).

The sample size was determined using Yamane’s (1967) formula:

$$n = \frac{N}{1+N(e)^2} \qquad \text{(Eq. 1),}$$

In Eq. 1, n = total household sample number, N = total population, and e = error term, which we set at 0.05. Thus, our total household sample number for all five kebeles in the study was determined from

$$\frac{10122}{1+10122(0.05)^2} = 385.$$

The formula for determination of the needed number of households in an individual kebele was:

$$S = \frac{TNH\ X\ TSH}{THS} \qquad \text{(Eq. 2)},$$

where S is the number of needed household samples for each kebele, TNH is the total number of households in a kebele, TSH is the total number of sample households, and THS is the Total households of all sample kebeles. Thus, for instance, Nabega kebele,

$$\frac{2283*385}{10122} = 87.$$

Table 3.3 Selected kebeles including the sample population from each selected kebele

N^o	Name of kebeles	Total household head [a]	Sample [b]
1.	Nabega	2283	87
2.	Shina	2136	81
3.	Kidest Hana	1790	69
4.	Shaga	1515	57
5.	Wagetera	2398	91
	Total	10122	385

Source: Central Statistical Agency (2007)

[a] The data was taken from the Ethiopian Central Statics Agency (CSA), [b] the data was found from sample respondents using the formula of Yemane (1967)

Fig. 1.7 Focus Group Discussions with kebele participants

After determining the sample size for the household survey, respondents were selected from each kebele by employing a simple random sampling technique. Accordingly, 385 farming households were selected randomly from each kebele proportional to the total population size in each kebele. About participants in focus group discussions and key informant interviews, the selection was made based on the purpose of the study. In other words, participants for focus group discussion, and key informant interviews were selected purposively since the purpose was to complement the quantitative data collected through household surveys. Accordingly, participants with relevant knowledge and experiences were selected purposively to participate in focus group discussions and key informant interview sessions. Accordingly, a total of five focus group discussions were administered for the study and seven participants participated in each focus group and participants were from different stakeholders in each study kebele (the stakeholders such as kebele administration leader, cooperative leader, youth, women, traditional and culture groups (“Equb”[1],“Edir”[2] and "Senbetie”[3]).

Moreover, interviewed farmers/key informants were also selected based on their living experience and job in the wetland areas and expertise working in this field. Selected households were interviewed in each kebele. The number of households interviewed

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[1] Equb እቁብ/ቁብ Amharic A rotating credit association in which each of its members contributes money periodically and the amount collected at each period is provided to one of the members often on a lottery system

[2] Edir እድር Amharic Edir is a traditional community organization in different parts of Ethiopia whose members assist each other during the mourning process.

[3] Senbetie:/ ሰንበቴ This is a religion believes that the groups of people drink local alcohol (Local name “Tila”) every month of Sunday prepared turn by turn for their soul.

in each kebele was 3 in number and the total number of households interviewed for five kebeles was 15.

About methods of primary data collection, the study employed a household survey questionnaire, focus group discussion, key informant interview, and personal observation. The sources of the primary data included local farming households, different stakeholders, and the natural environment in the study area.

Close-ended, semi-structured, and open-ended questionnaires were prepared in English language and translated into the local language (Amharic) to be clear for the respondents. The respondents who couldn't read and write responded with their answers with the help of the enumerators.

About the administration of the household survey questionnaire, five enumerators were selected and trained before the administration of the household survey questionnaire, and they managed the collection of the relevant data from the respondent households from each kebele with close supervision of the researcher himself. On the other hand, the administration of the focus group discussions, and the key informant interview sessions were facilitated by the researcher himself since close facilitation, and supervision were required for in-depth qualitative data generation (Fig. 3.7). Field observations were made to collect data about the land use of the study area. GPS points were also used to collect data for the training site to do ground verification (Fig. 3.8).

The study also employed secondary methods of data collection to collect relevant secondary data on weather, demographic, and other relevant geospatial data from different secondary sources.

Landsat Thematic Mapper (TM), Multi-Spectral Scanner (MSS) imagery for the period 1973 was bought from the Ethiopian Mapping Agency (EMA) and 2021 downloaded from the United States Geological Survey (USGS) Earth Resources Observation Systems (EROS) data center under the Landsat Archive. In addition, pre-processing and post-processing were done for satellite images. These images were projected to UTM zone 37 north and masked by the study area.

Then unsupervised and supervised image classification was done on the post-processing. The unsupervised classification was used in the image classification before fieldwork to understand the general land cover classes of the study area. This is because unsupervised classification is automated and requires little knowledge of the study area. According to their spectral signature using different band combinations, the classified images were assigned a class in the output raster.

Supervised classification was applied in the unsupervised classification signatures using the field survey data to identify the major land use land cover classes in the satellite imagery. Therefore, using GPS ground truth data was collected. Then, class assignment and naming were done using the original images, and field experience to identify the various land use land cover classes. To view and discriminate different surface features clearly, different band combinations were used which magnify a particular class in the image.

In addition, Landsat images for land use land cover mapping, and ground truth data were collected for land use classification signatures (Table 3.4). Vegetation was sampled for biodiversity and evenness analysis using standard sampling every 100 m distance along the longest cross-section of the study area and taking a 1 m^2 plot for identifying types and counting the number of species in three Kebeles (Appendix II Table 4.33). The collected plant species were taken to Bahir Dar University to identify species types and their scientific name. Dr. Ayalew is an expert on wetland species of plants at Bahir Dar University.

Climate data such as rainfall (CHIRPS) and temperature (ERA5), digital elevation model (USGS website), soil map, shapefiles (BCEOM 1998), map of Rib watershed, and land use/land cover map were collected and used as an input for hydrological analysis of floodplain rivers including Ribb River using SWAT model. In addition, Ribb observed flow data (MoWIE) for validating simulated flow data, modeled and secondary data of Nitrogen (N) and Phosphorus (P) from (Abebe *et al.,* 2021) and (Negash *et al.,* 2011) for water quality analysis and normalized difference vegetation index (NDVI) data (MODIS from https://doi.org/10.5067/ASTER/ASTGTM.003) (accessed on 16 September 2020) for vegetation cover trend analysis were also collected. To verify the NDVI classes (range) with the existing cover of rice fields, water bodies and dense vegetation, the ground truth of 30 points for rice fields, 30 points for dense vegetation, and 30 for water and others (emergent aquatic vegetation) were collected from June to September (wet season) 2018 (Fig. 3.8)

Table 3.4 Data Type and Sources

S.N.	Data Type	Spatial Resolution	Source
1	Landsat 8 image	30 m	USGS Landsat images
2	DEM SRTM, 2000	30 m	NASA/USGS/JPL-Caltech
3	NDVI	250 m	MODIS from: https://doi.org/10.5067/ASTER/ASTGTM.003 (accessed on 16 September 2020)
4	Rib River flow, 1981–2005	discharge in m^3s^{-1}	MoWIE, Ethiopia
5	Precipitation, 1981-now	0.25^0	CHIRPS 2.0 Africa
6	Temperature, Minimum/Maximum, 1981-now	0.25^0	ERA5 Africa
7	Soil	1:250,000	MoWIE, BCEOM. (Abebe *et al.*, 2021)

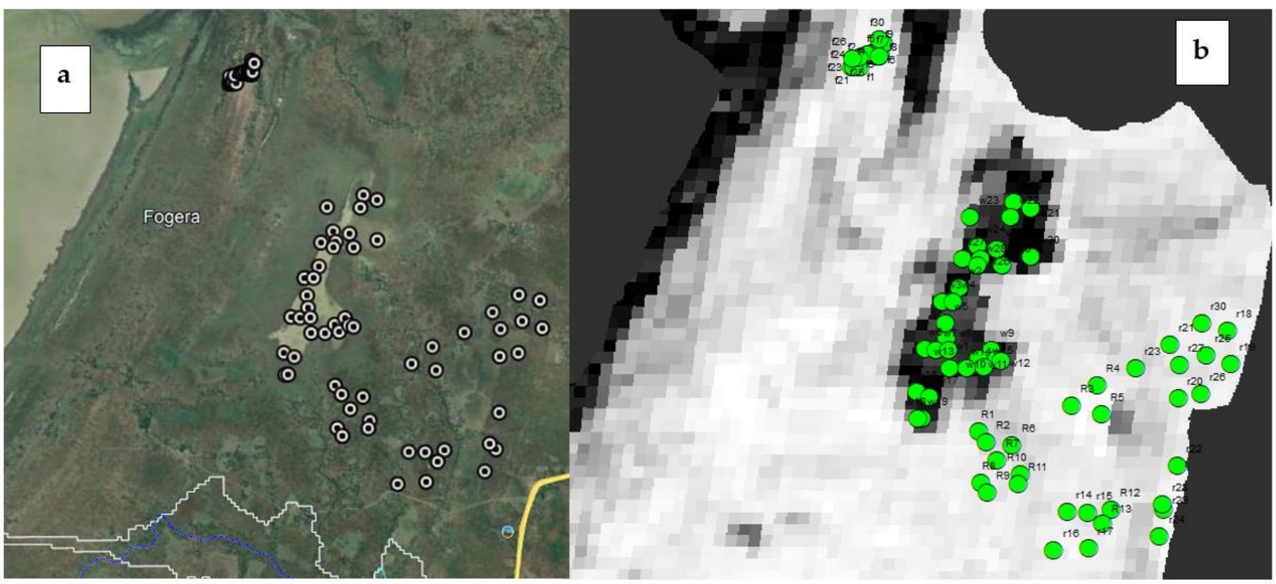


Fig 3.8 Land use/cover ground truth points in the Fogera floodplain

(**a**) Map a showed the ground truth points mapped on Google Earth (white circles), and
(**b**) Map b showed the ground truth points mapped on NDVI map (green circles).

The hydrological data: Daily precipitation data of the Amed Ber, Woreta, Addis Zemen, and Yifag stations were collected from the Ethiopian Meteorological Agency (EMA), situated in the North West Region of Meteorology branch, Bahir Dar. The dataset was not up to date or complete for all stations. Therefore, remote sensing precipitation data from the Climate Hazards Group InfraRed Precipitation with Station Data (CHIRPS) with 0.05 arc degree resolutions were downloaded for the period 1 January 1981 to 30 September 2019 using the Google Earth Engine cloud computing platform and the KNMI climate explorer website as input in SWAT (Funk *et al.,* 2015). CHIRPS was chosen because it holds long-term daily data with the best resolution and performance for this location platform (Funk *et al.,* 2015). The hydrology was characterized for the entire floodplain using Ribb River data at the lowest gaging station located at 12.00 N and 37.716 E.

The flow data of the floodplain were generated using the SWAT 2012 model. The Ribb River observational flow data for the calibration were obtained from the Ministry of Water, Irrigation, and Electricity (MoWIE, 1991), spanning from 1985 to 2014. Nitrogen and Phosphorous flow data for all the sampling sites were generated using the SWAT model (version 2012.10.4.21). Calibration, validation, and uncertainties were obtained using SWAT-CUP version 5.2.1.1 for the entire Ribb catchment considering the observed flow data of the lower gaging station—No. 111006, sampling site LR05 (Fig. 3.8 and Table 3.4)

3.4. Data Analysis

3.4.1. General analysis

Data from interviews and local government reports were cross-tabulated among kebeles using the XTAB module of SYSTAT v. 13.1. Standard deviates were calculated from (Observed Value-Expected Value)/SQR(Expected Value) and used to determine deviation from the model of independence, which assumes responses to a particular survey question were independent of kebele, from Chi-Square tests of Association (SYSTAT, 2009). Analysis of variance was made when variance existed for quantitative data, and significant differences among kebeles were tested using Tukey's hsd in SYSTAT 13.1.

The quantitative data were analyzed using percentage, mean, and correlation in Excel and summarized using SPSS version 21, and the qualitative data through narrative analysis and thematic analysis. Pearson's correlations were used for water flow, Nitrogen (N), and Phosphorus (P) that indicate water pollution status. Indicators of Hydrological Alteration (IHA) software was used to figure out environmental flow components and analyze flow alterations of the Ribb River which floods to the Fogera floodplain (Nature Conservancy (TNC), 2009). Image processing and analysis were performed using ArcGIS10.4 software and accuracy assessment was also employed. SWAT2012 for flow and nutrient simulation and SWATCUP for calibration and uncertainty analysis were also used. Ribb observed flows between 1981 to 1999 and 2000 to 2004 were used for calibration and validation, respectively.

NDVI data for the years 2000, 2009, and 2018 were generated using the Google Earth Engine, a cloud computing platform, to see rice expansion in the area. The NDVI was used to identify the rice, dense vegetation and water bodies, and other small grass areas within a wetland classified in ArcGIS 10.4 environment based on signatures suitable threshold indices values for rice 0.4–0.71 (Average = 0.66 and STDEV = 0.03), dense vegetation > 0.71 (Average = 0.71 and STDEV = 0.01), water and others < 0.4 (Average = −0.04 and STDEV = 0.08) based on Tucker, C.J. and P. Sellers (1986) and the ground truth collected during the study period from June to September (wet season) 2018. The formula for calculating Normalized Difference Vegetation Index **(NDVI)** is the following: NDVI = (NIR – Red)/(NIR + Red) ----------------Eq 3

Where, NIR is near-infrared light and Red is visible red light.

Shannon Diversity Index (H') was also used to compute the diversity and composition of herbaceous and grass species of the wetlands in the Fogera floodplain (Shannon and Weaver 1949). This index takes into consideration species composition and evenness within the given area calculated using Equations (3) and (4) as follows:

$$\mathrm{H}' = -\sum_{i=1}^{s} Pi\ (\mathrm{In(pi)}, \qquad pi = \frac{ni}{\mathrm{N}} \qquad \text{Eq 4}$$

$$\textbf{Evenness (J):}\ \mathrm{J} = \frac{\mathrm{H}}{\mathrm{Hmax}} \qquad \text{Eq 5}$$

where ni = number of individuals of species "*i*", N = total number of individuals of all species, *p*i = relative abundance of species "*i*", *S* = total number of species, and H' = the Shannon Diversity Index. (**Note:** For the Shannon Diversity Index (H'), the research took only three kebeles because the other two kebeles are similar in every situation)

Analysis of variance (ANOVA) was used to analyze the livestock unit. The LEVENES test was used to check the homogeneity of variance (SAS 9.4 version). The data collected through FGD and interviews were also analyzed through qualitative description or narration.

Estimation of available feed resource and land use Dry matter (DM) yield of natural pasture and the quantity of feed DM obtained annually from different land-use types was calculated by multiplying the hectare of land under each land-use type by its conversion factors. The conversion factors of 2.0, 1.5, 1.3, 1.2, and 1.2 t DM/ha/ year were used for natural pasture, teff (*Eragrastis tef*), rice (*Oryza sativa L*), grass pea (*Lathyrus sativus*), and chickpea (*Cicer arietinum*), respectively (Tibebu *et al.*, 2018). The quantity of available crop residues (dry matter basis) on the current crop production system was estimated from the total crop yields of the households using the above conversion factor. The amount of dry matter obtained from communal grazing land is factored into communal grazing areas for each total household and their associate tropical livestock units (TLU) eligible to graze on this land unit.

Estimation of balance between feed supply and demand

The livestock population was converted into tropical livestock units (TLUs) using the approach in (Tibebu *et al.*, 2018) for comparison purposes.

Available DM per year from natural pasture and crop residues was compared to the annual dry matter requirements of the livestock population in the sampled households. The DM requirement of the livestock population was calculated based on the daily DM requirement of 250 kg dual-purpose tropical cattle (an equivalent of one TLU) for maintenance requirement that needs 6.25 kg/ day/animal or 2281 kg/year/animal (Tibebu *et al.*, 2018).

Land use/land cover analysis image processing for the land use analysis was done using ArcGIS 10.4. Change matrixes were done to interpret change in grazing land in the years 1973 and 2021. Data from Woreda agriculture offices were used to compare results from the land use analysis. The area covered by each land use/land cover (LULC) class was calculated, and subsequently, the changes were compared for the periods 1973 and 2021.

Total Land use/land cover in the study area includes forest land, agricultural land, water bodies, wetlands, and grasslands/grazing. Land use/land cover (LULC) classification schemes used in this study include the following variables (Thompson, 1996):

Forest areas: Areas dominated by trees having a height of 6 m and above which have a crown cover overlap of 15% or more (Intergovernmental Panel on Climate Change) (IPCC, 2019)

Bush and Shrub Land: Land with shrubs/bushes canopy cover ≤ 10% or combined cover of bush, and shrubs ≤10%. Shrubs and bushes are woody perennial plants, 2 m in height at maturity in situ (IPCC, 2019)

Agricultural lands: These are land covers used to cultivate perennial or annual crops.

Water body: Areas covered with ponds and small lakes. Grasslands: Areas with permanent grass cover located on a plain and water logging areas.

Wetlands: are those areas dominated by wetland herbaceous vegetation or are non-vegetate where the water table is at, near, or above the land surface for a significant part of most years (IPCC, 2019)

The hydrology of the wetland was analyzed. River flow regime changes and indices were analyzed using Indicators of Hydrological Alteration (IHA) software version 7.1 (Nature Conservancy (TNC), 2009). Setting up and completing the analysis in IHA involved the use of hydrologic data as the input, deciding analysis years, and water year starting Julian date ((TNC) 2009). Hydrological data for the Ribb River collected from 1981 to 2018 were imported in CSV file format and saved as an internal hydrologic file. A project was then created, linked to a single hydrologic data file, and used to create and run multiple analyses.

The water year was set to start on January 1 and end on December 31, which is suitable for floodplain flow conditions. In addition, image processing for land use analysis was performed using ArcGIS10.4. Change matrices were developed to interpret the change in the wetland for the years 1973 and 2021. The area covered by each land use land cover (LULC) class was calculated with an accuracy assessment result of 100% and, subsequently, the changes were compared for the years 1973 and 2021. The LULC classification scheme used in this study was adapted from Namugize *et al.,* (2011).

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Farm Household Head Characteristics and Perceptions of Factors Related to Sustainable Management of Wetlands

4.1.1.1. Kebele Household Profiles

There were similarities among kebele household heads in religion, gender distribution, and other characteristics, but also important differences. All 385 respondents from the five kebeles identified as Orthodox Christians. Household heads were mostly men, with 94% of households headed by men and only 6% headed by women (Table 4.1). Kebele household heads were also similar in marital status, although Shena household heads tended to have a lower divorce rate i.e. zero (Table 4.2).

Table 4.1 Gender distribution among household heads in five kebeles of the Fogera Wetlands

				Standard Deviates	
Kebele	Male	Female	Total	Male	Female
Kidest Hama	65	4	69	0.015	-0.06
Shaga	76	5	81	-0.018	0.073
Shena	54	3	57	0.055	-0.22
Wagetera	85	6	91	-0.061	0.242
Nabega	82	5	87	0.022	-0.087
Total	362	23	385	p-value=0.998	

Note: Colors are used to indicate positive (blue) or negative (red) deviation from the model of independence, which assumes responses to a particular survey question were independent of kebele. P-values indicate the significance of differences among kebeles.

Table 4.2 Marital status of household heads in five kebeles of the Fogera Wetlands

					Standard Deviates		
Kibele	Married	Unmarried	Divorced	Total	Married	Unmarried	Divorced
Kidest Hama	65	3	1	69	0.015	-0.22	0.334
Shaga	76	4	1	81	-0.018	0.001	0.173
Shena	54	3	0	57	0.055	0.112	-0.77
Wagetera	85	5	1	91	-0.061	0.24	0.056
Nabega	82	4	1	87	0.022	-0.142	0.101

Total	362	19	4	385	p-value=0.999

Household heads differed significantly (p=0.000) among kebeles for age distribution (Table 4.3 and Fig. 4.1A). Kidest Hana had fewer household heads in the age group of 20 to 40 years, but more in the age group of 40 to 69 years. Shaga had more household heads aged 60 to 69 years old compared to other kebeles and fewer that were 50 to 59 years old. Shena had more household heads in the 20 to 39-year-old age groups, but fewer aged 40 and older. Similarly, Wagetera household heads tended to be younger, particularly in the under 20 to 29 age groups, and to have proportionally fewer people in older age groups. Nabega tended to have more heads in the 50 to 59 year-old age group, and fewer in the 60 to 69 year-old age group, but was the only kebele to have household heads (3) in the 70 to 79 year-old age group. Kidest Hana had the highest mean age of 51.2 years, and Shena had the youngest mean age of 42.9 years. The box-and-whisker plot of age distribution among Kebeles (Fig. 4.1B) further illustrates differences among Kebeles for age distribution.

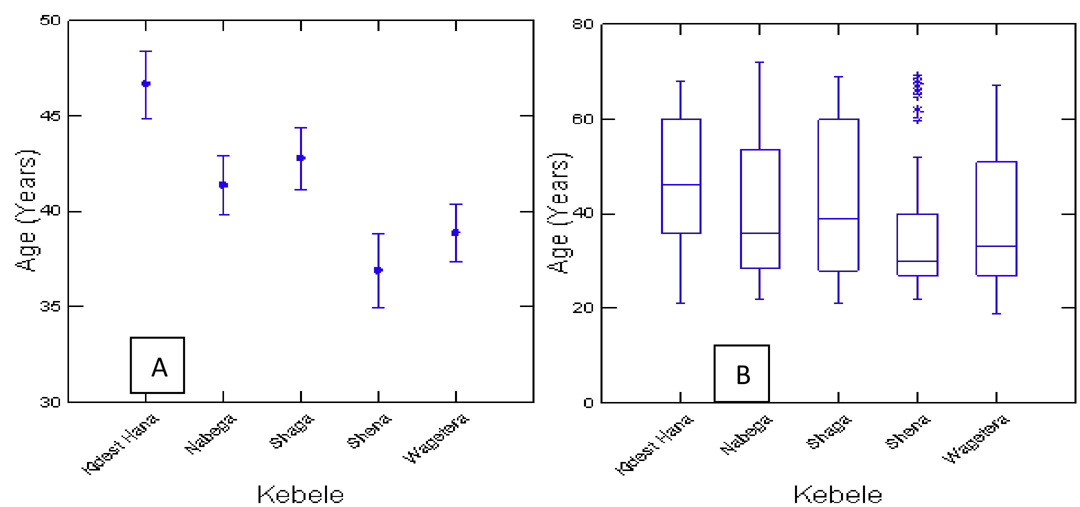


Fig. 4.1 Household head age among five kebeles of the Fogera wetlands

A) Mean ± one standard error; B) Box-and-whisker plot.

Table 4.3 Household age distribution among household heads in five kebeles of the Fogera Wetlands

Kebele	Under 20	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79
Kidest Hama	0	12	8	21	10	18	0
Shaga	0	23	18	12	3	25	0
Shena	0	23	17	6	1	10	0
Wagetera	1	33	24	9	5	19	0
Nabega	0	24	23	12	12	13	3
Total	1	115	90	60	31	85	3

Standard Deviates

Kebele	Under 20	20 to 29	30 to 39	40 to 49	50 to 59	60 to 69	70 to 79
Kidest Hama	-0.423	-1.897	-2.024	3.125	1.885	0.709	-0.733
Shaga	-0.459	-0.243	-0.215	-0.175	-1.379	1.683	-0.794
Shena	-0.385	1.448	1.007	-0.967	-1.676	-0.729	-0.666
Wagetera	1.571	1.116	0.591	-1.376	-0.86	-0.243	-0.842
Nabega	-0.475	-0.39	0.59	-0.423	1.887	-1.416	?
	p-value=0.000						

Note: Colors in the tables above are used to indicate positive (blue) or negative (red) deviation from the model of independence, which assumes responses to a particular survey question were independent of kebele. P-values indicate the significance of differences among kebeles.

There were also tendencies for level of education differences among kebele household heads (Table 4.4). The p-value of 0.293 (Table 4.4) suggests that the model of independence between kebele and education did not deviate quite as strongly from independence as that for kebele and age. Even so, Wagetera and Nabega tended to be the best educated, with proportionally more literate household heads than other kebeles. Wagetera household heads tended to have more primary school education. Kidest Hana and Shaga tended to be the least educated, with higher proportions of illiterate household heads, and lower proportions of literate household heads. None of the 385 household head respondents from the five kebeles had any secondary or tertiary education.

Table 4.4 Education level among household heads in five kebeles of the Fogera Wetlands

Education					Standard Deviates		
Kebele	Illiterate	Literate	Primary School	Total	Illiterate	Literate	Primary School
Kidest Hama	60	8	1	69	0.546	-1.199	0.11
Shaga	71	10	0	81	0.661	-1.139	-1.026
Shena	47	10	0	57	0.119	-0.021	-0.86
Wagetera	69	20	2	91	-0.553	0.98	0.753
Nabega	65	20	2	87	-0.655	1.182	0.819
Total	312	68	5	385	p-value=0.293		

Data suggests that most household heads had 3 to 4 children, but there was a slight tendency for Kidest Hana and Nabega households to have larger (>4 children) families (Table 4.5).

Table 4.5 Number of children in households in five kebeles of the Fogera Wetlands

	Number of children						
Kebele	1	2	3	4	5	6	Total
Kidest Hama	0	2	41	25	0	1	69
Shaga	2	2	44	32	1	0	81
Shena	1	1	35	20	0	0	57
Wagetera	1	2	50	35	3	0	91
Nabega	1	2	49	31	4	0	87
Total	5	9	219	143	8	1	385

Standard Deviates						
Kebele	1	2	3	4	5	6
Kidest Hama	-0.947	0.305	0.279	-0.124	-1.197	1.939
Shaga	0.924	0.077	-0.306	0.349	-0.527	-0.459
Shena	0.302	-0.288	0.453	-0.255	-1.088	-0.385
Wagetera	-0.167	-0.087	-0.245	0.206	0.807	-0.486
Nabega	-0.122	-0.024	-0.069	-0.231	1.63	-0.475
	p-value=0.850					

Note: Colors in the tables above are used to indicate positive (blue) or negative (red) deviation from the model of independence, which assumes responses to a particular survey question were independent of kebele. P-values indicate the significance of differences among kebeles.

4.1.1.2. Kebele Farms

The total area farmed by the 384 households in the five kebeles was 340.8 ha. Of this amount, 263.3 ha were sown to rice, 36.0 ha to grass pea, 21.8 ha to teff, 8.5 ha to onion, 3.8 ha to tomato, and 2.5 ha to chickpea (Fig. 4.2). There were significant differences (p=0.000) among kebeles for total farm size, with Kidest Hana having the largest mean farm size of nearly 1.3 ha, and Nabega having the smallest with a mean area of 0.80 ha (Fig. 4.2). Kidest Hana farmers seemed to be the most successful compared to other kebeles, with greatest area farmed to rice (p=0.000), grass pea (p=001), onion (p=0.001), and garlic (p=0.000) (Fig. 4.2).

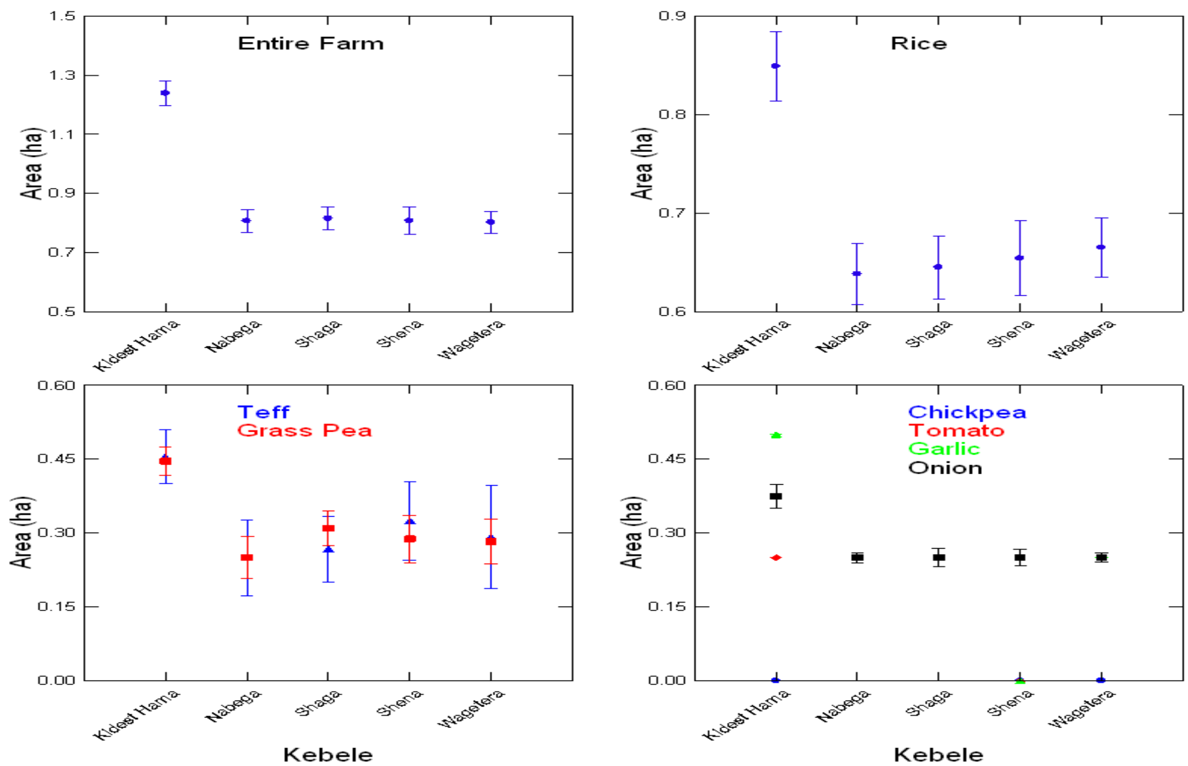


Fig. 4.2 Total area farmed and areas cultivated

Note: The figure explained total area farmed and areas cultivated to seven crops among five kebeles. Data points represent mean values and error ticks one standard error.

They tended to have the greatest area sown to teff as well (p=0.135) but variability for teff area among farmers within kebeles was high. Nearly all farmers grew rice during the rainy season irrespective of kebele (Fig. 4.3). Depending upon the kebele, from 24 to 39% of farmers grew teff, and 16-52% grew grass pea (Fig. 4.3). Onion, garlic, and tomato, which are typically grown during the dry season in fields distant from rice fields and require irrigation, were only grown by a small minority of farmers. Only a very small proportion of farmers grew chickpeas, and all of these were in either Shaga or Nabega kebeles.

Kidest Hana farmers had by far the greatest yield for rice, or 3416 kg ha^{-1}, followed by Shaga, Wagetera, Nebega, Shena, and final Nabega, where mean rice yield was only 1884 kg ha^{-1} (Fig. 4.3). Nabega had greatest yields for onion (p=0.000), and Nabega and Wagetera for tomatoes (p=0.000). Kidest Hana had the greatest garlic yields (p=0.000), and Nebega had the greatest chickpea yields (p=0.000).

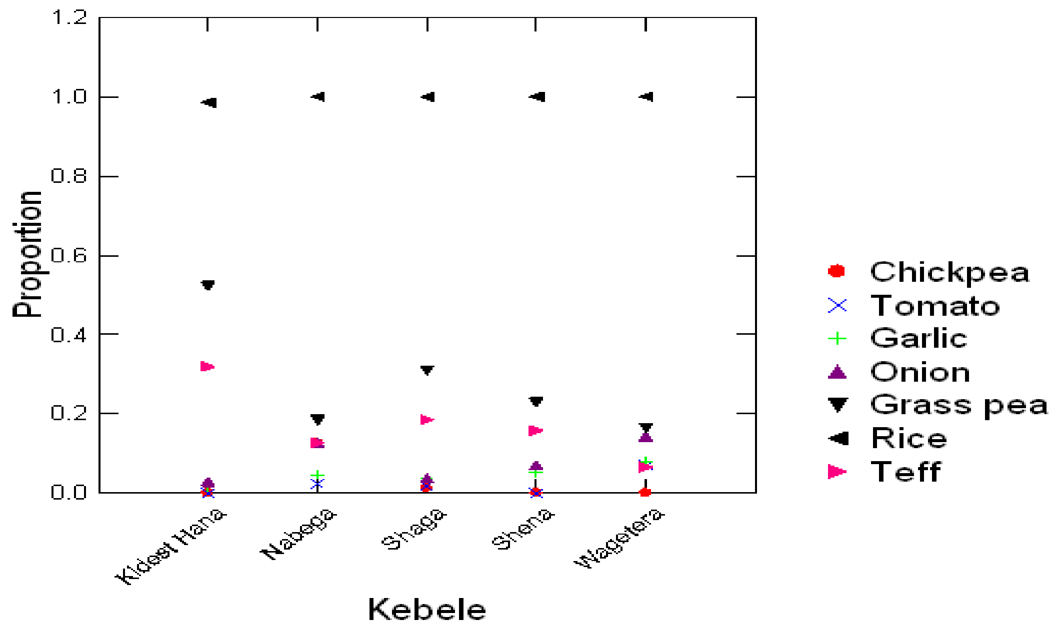


Fig. 4.3 Proportion of respondent farmers in five kebeles growing seven crops

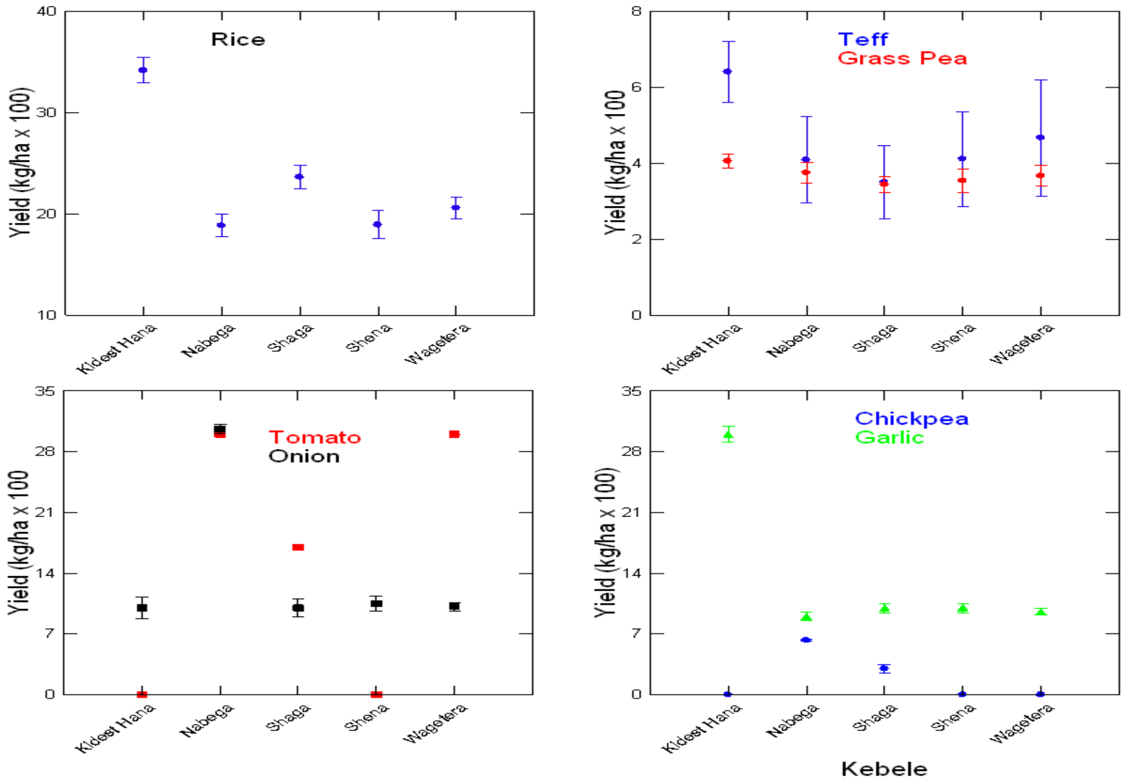


Fig. 4.4 Yield of seven crops at five sample Kebeles

Data points represent mean values and ticks one standard error. Error bars are uneven because not all farmers grew all crops). In some cases, standard errors are zero either because only one or no farmers grew that crop or there was no variance, i.e. all reported the same yield. In general, the cash crops tomato, garlic, onions, and to a lesser extent chickpea were sold at much higher proportions of 0.9 or more (Fig. 4.4). Much lower proportions of the staple food and fodder crops (rice, teff, and grass pea) were sold, with values ranging from ~0.3 to ~0.7.

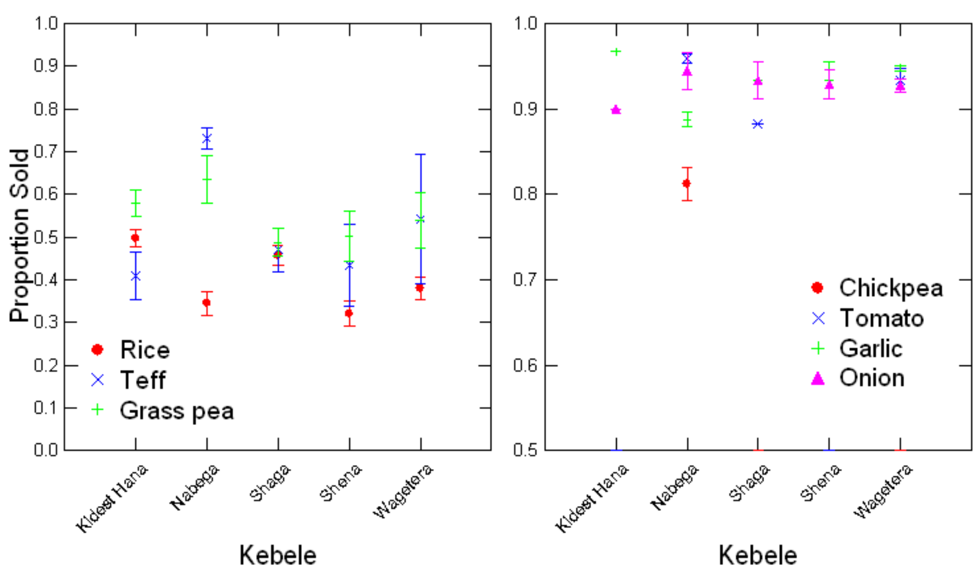


Fig. 4.5 Ratio of produced crops

Note: The Figure explained that the ratio of produced crops that were sold to that consumed among different kebeles in the Fogera wetlands for rice (left) and other crops (right).

Nonetheless, there were significant differences among kebele farms for percentages sold for rice (p=0.000), teff (p=0.007), chickpea (p= 0.000), tomato (p=0.016), and garlic (p=0.002). Kidest Hana sold the largest proportion, or 0.50, its rice, and Shena the least, or 0.32. In contrast, Kidest Hana sold the smallest proportion (0.41) of its teff, and Nabega sold the largest proportion (0.73). Overall, data suggest that Nabega and Shena produced rice for food consumption and had lower incomes, for they kept more of their rice, sold more of the relatively expensive teff, and raised more cash crops to sell for income. There were some relations between household head characteristics and kebele farms. Older household heads tended to have more land than younger ones (Fig. 4.5), with a handful of older farmers having large holdings of two or more ha. Those with three or four children tended to have more land area than those with more than five or less than three children. Married household heads had more land than those divorced or unmarried, with mean areas of 0.91 ha for married heads and 0.45 ha for unmarried heads and for divorced heads. Total farm size was significantly correlated with area cultivated to teff (p=0.022) (Fig. 4.6).

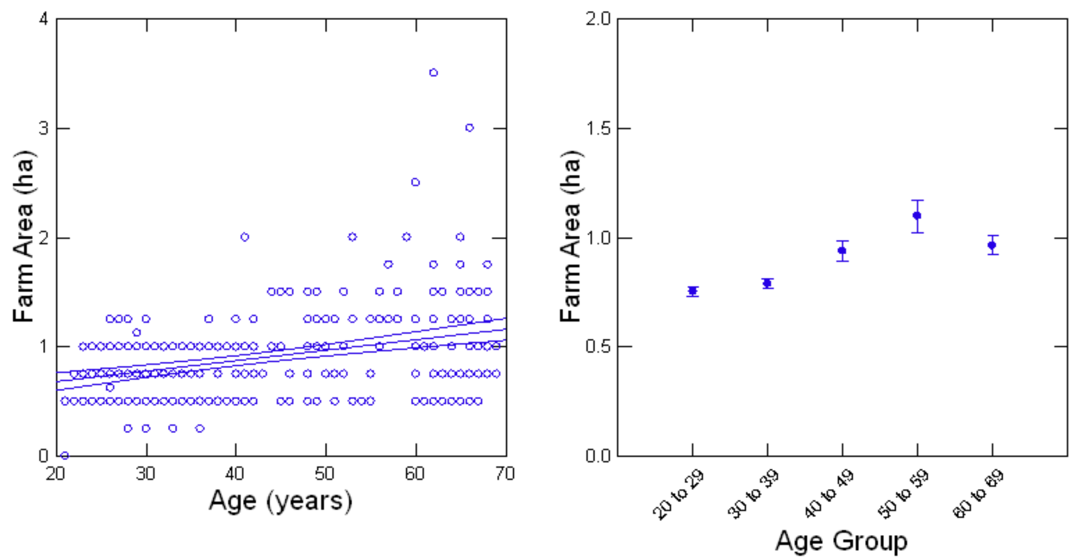


Fig. 4.6 Farm size among different age groups

Note: Left: all respondents with a fitted linear curve and 95% confidence interval. Right: Means ± one standard deviation. Data for groups <20 years old and >70 old are omitted from the right graph due to the low number of respondents in these age groups (1 for <20, 3 for >70).

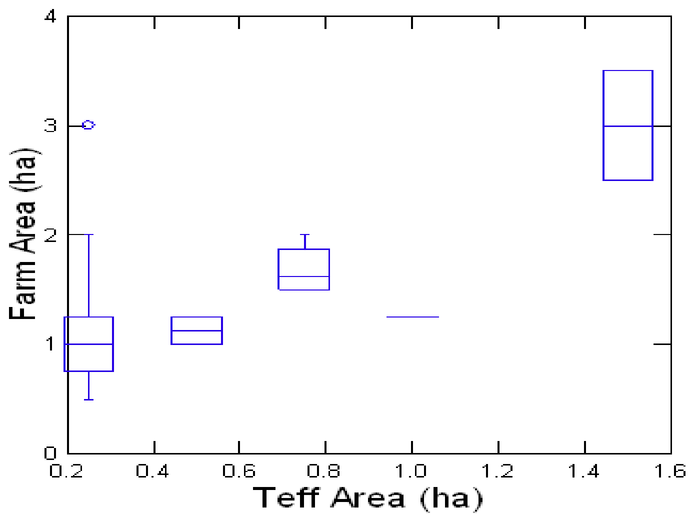


Fig. 4.7 The relationship between total farm area and sown area

The relationship between total farm area and area sown to teff among 384 farms located in five kebeles of the Fogera Wetlands illustrated that teff takes the highest land holding of farmers in the floodplain (Fig. 4.7).

4.1.1.3. Wetland Management

Household head responses to questions concerning sustainable wetland management revealed both similarities and differences among kebeles. Not a single respondent felt that the land was public or that anybody outside their kebele could use the natural resources (Table 4.6). Overall, 85% of respondents thought wetland ownership was communal, or a CPR available to the kebele, while only 15% thought land was privately owned. However, chi-square tests showed clear differences among kebeles for their perceptions of land ownership (p=0.000). Household heads in Shena and Nabega tended to perceive more strongly that land ownership was private, while Kidest Hana and Shaga tended to perceive it more strongly as communal. A large percentage (44%) of the respondents didn't know who was responsible for overseeing land management (Table 4.6). About 22% thought the community was responsible for land management and an equal percentage of respondents thought a development agency was responsible. Only a minority or 12% thought that the kebele leader was in charge of land management. There were tendencies for kebeles to perceive this differently, with Shena viewing the role of the kebele leader as particularly weak, and Nabega viewing it as particularly strong.

Remarkably, all the respondents unanimously indicated their unfamiliarity with any governmental or non-governmental organizations working on sustainable management of the wetlands. Irrespective of kebele, age, level of education, or gender, all responded that they did not know of any organization devoted to wetland wellbeing.

Regarding perceptions of ways in which individuals might contribute to improved sustainable wetland management, 75% of the respondents said they would attend meetings on the topic. Fewer people were interested in punitive measures against illegal users (12%) or in actively participating in a committee charged with improving management (12%). There were no differences on this among kebeles (Table 4.6). Respondents were unanimous on the lack of mechanization in their rice fields. Given the small parcels of land even for the largest farms, this does not seem surprising. The response to the last question, whether household heads had taken other crops out of production to produce more rice, by far the most common response (87% of respondents) was no. Table 4.7 farm household head perceptions of ownership of wetlands were found independent from kebele with P-values indicating the significance of differences among kebeles.

Table 4 6 Farm household head perceptions of kebele households on ownership of wetlands

	Perception of Ownership			Standard deviates		
	Private	**Communal**	**Total**		**Private**	**Communal**
Kidest Hana	6	63	69	Kidest Hana	-1.363	0.574
Shaga	4	77	81	Shaga	-2.348	0.989
Shena	13	44	57	Shena	1.506	-0.634
Wagetera	11	80	91	Wagetera	-0.732	0.308
Nabega	24	63	87	Nabega	3.009	-1.267
Total	**58**	**327**	**385**	p-alue=0.000		

Table 4.6 indicated that farm household heads perceptions of who is responsible for sustainable management of the wetlands. Colors are used to indicate positive (blue) or negative (red) deviation from the model of independence, which assumes responses to a particular survey question were independent of kebele. P-values indicate the significance of differences among kebeles.

Table 4.7 Farm household head perceptions of who is responsible for sustainable management of the wetlands

Who is Responsible						Standard deviates				
	Community	**Kebele Leader**	**Development Agent**	**Don't know**	**Total**		**Community**	**Kebele Leader**	**Development Agent**	**Don't know**
Kidest Hana	17	9	14	29	69	Kidest Hana	0.501	0.199	-0.227	-0.297
Shaga	16	8	16	41	81	Shaga	-0.398	-0.6	-0.35	0.838
Shena	11	3	14	29	57	Shena	-0.407	-1.501	0.488	0.732
Wagetera	22	12	20	37	91	Wagetera	0.481	0.267	0.086	-0.538
Nabega	18	15	19	35	87	Nabega	-0.225	1.344	0.056	-0.586
Total	**84**	**47**	**83**	**171**		p-value=0.803				

There was no association of the various respondent groups for their responses to perceptions on sustainable wetlands management—i.e., among gender, education, number of children, marital status, etc., except for the first question on who owned the land, which was associated with total farm size. This, however, would seem to be an artifact of the responses of household heads in Kidest Hana and Shaga, who had the largest farms, and the greatest tendency to perceive the land as communally owned.

4.1.2. Temporal and Spatial Changes in Crop Patterns, Use of Inputs and Hydrological Alteration

4.1.2.1. Spatial and Temporal Trends in Crop Production Patterns

Spatial and temporal patterns in the area's crop production pattern based on three NDVI image classes showed that the rice crop cultivated land increased at a rate of 1198 with R^2 of 0.8 whereas dense vegetation, water, and other small vegetation showed decreasing trends at a rate of −251 and −948 with R^2 0.5 in the year 2000, 2009 and 2018, respectively (Fig. 4.8).

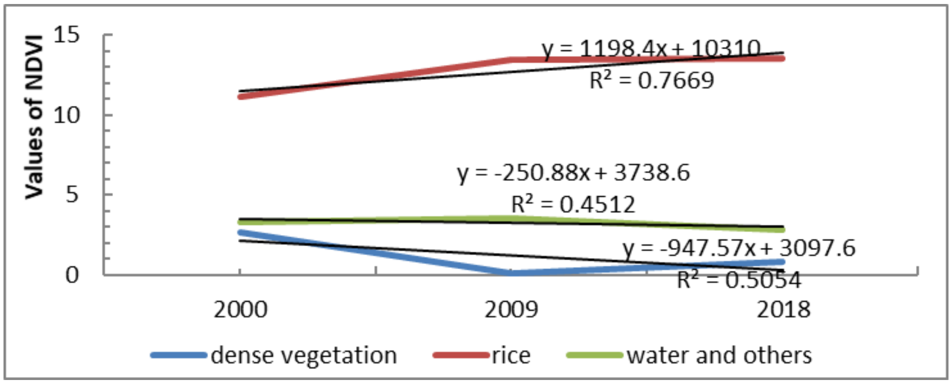


Fig. 4.8 The relationship between total farm area and sown area

The figure indicates that the NDVI of rice cultivated land, dense vegetation and water in the Fogera floodplain between 2000–2018. Furthermore, the spatial analysis of the NDVI values in 2000 for dense vegetation, rice, water and others indicated 2691 ha, 11,127 ha, and 3328 ha area coverages, respectively (Fig. 4.9a). The coverage in 2009 for dense vegetation was 120 ha for rice 13,469 ha, and water and others 3556 ha (Fig. 4.9b). In the latest analysis in 2018, the area coverage for dense vegetation, rice and water, and others was 796 ha, 13,523 ha, and 2826 ha, respectively (Fig. 4.9c). Hence, based on the spatial analysis, the area coverage for rice showed an increase while dense vegetation and water and others showed a decline. Overall, rice area increased by 2397 ha whereas "water and others" decreased by −502 ha.

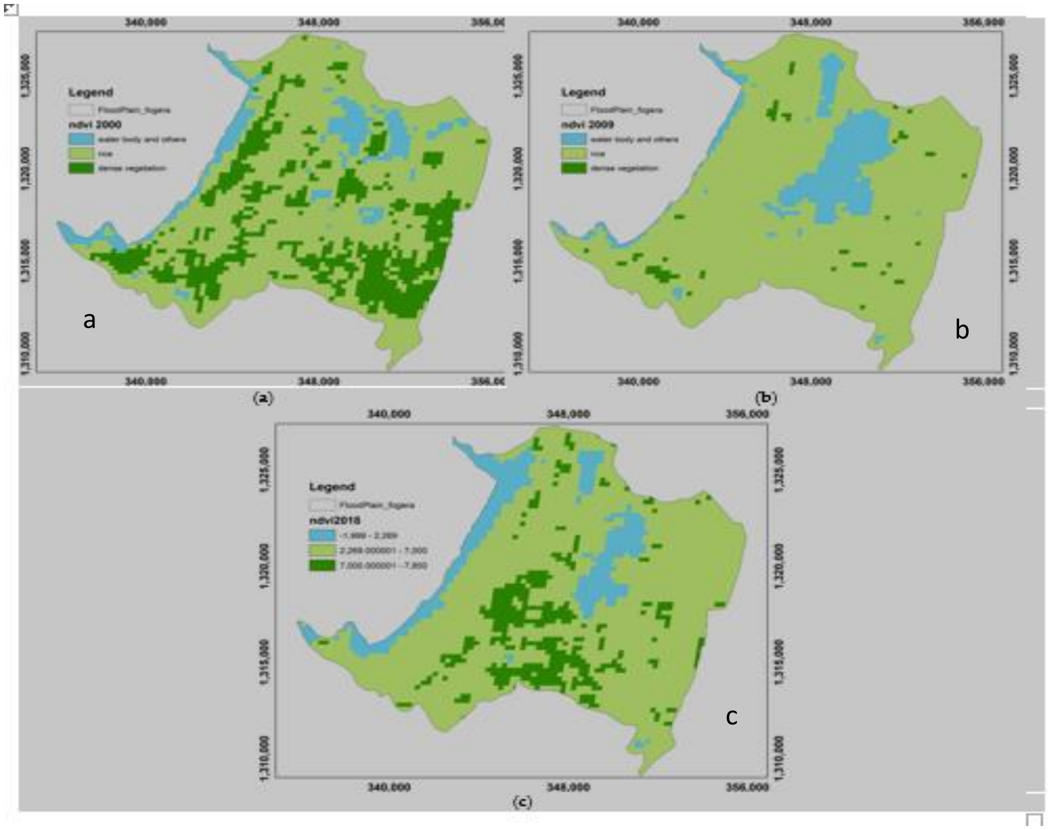


Fig. 4.9 Land covers maps of Fogera floodplain area

(**a**) Average NDVI classes from June to September (wet season) in 2000, (**b**) average NDVI classes from June to September in 2009, and (**c**) average NDVI classes from June to September in 2018

Accordingly, as indicated in Fig. 4.10, the sampled respondents mentioned that the size of their farmland before the introduction of rice was 158.75 ha but after the introduction of rice this number increased to 284.75 ha, or an increase of 126 ha (Fig. 4.10).

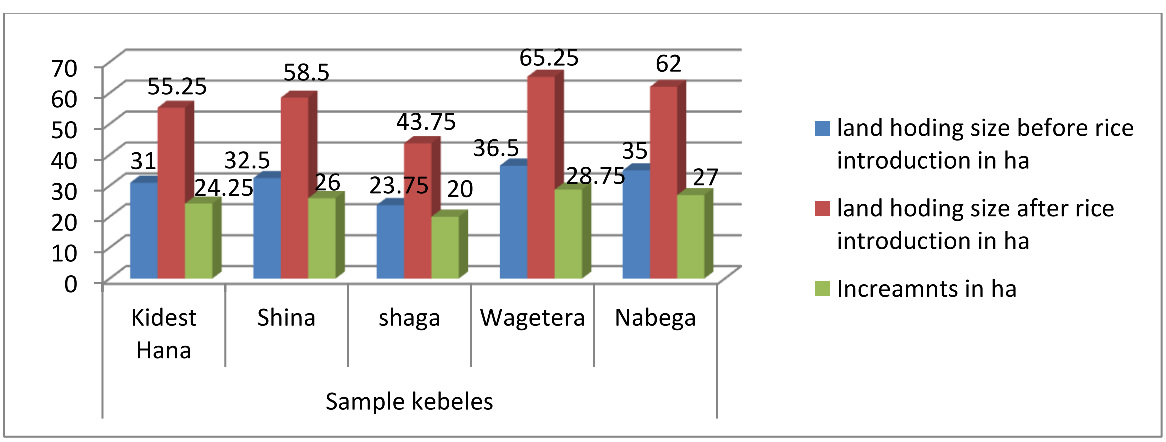


Fig. 4.10 Expansion of farmland for rice production in hectares (Ha)

Respondents were asked about their previous production style before the introduction of rice. They indicated that they produced different crops in the study areas, including small amounts of teff *(Eragrostis tef)*, maize *(Zea mays* L.*)*, noug *(Guizotia abyssinica*), finger millet *(Eleusine coracana*), chickpea *(Cicerarietinum)*, lentil *(Lens culinaris)*, grass pea *(Lathyrus sativus)*, green pepper *(Capsicum* spp.*)* and barely *(Hordeum Vulgare)*, and devoted a larger amount of land for animals. They also stated these minor crops were produced far away from the wetlands in the study site.

Most respondents reported being engaged in rice production during the summer season while, focused more on horticultural crops such as onion *(Allium cepa)*, garlic (*Allium sativum*), and tomatoes *(Solanum Lycopersicum)* in the winter season. These were grown using small-scale irrigation.

Regarding the area cultivated in the wetlands of the Fogera floodplain, the two-year data showed that the cultivated area coverage of the rice crop was 245.25 ha and 284.75 ha in the years 2014 and 2015, respectively (Table 4.8). In Fig. 4.11 the land-use coverage for rice and other land use for the years 2013, 2015, and 2016 are also mapped, and the result revealed the coverage for rice has shown an increment.

Table 4. 8 Cultivated area coverage of the rice crop for the year 2014 and 2015

Name of Sample Kebele	No. of Sample Respondent	2014	2015	Increment in ha
		Total Cultivated Land in ha	Total Cultivated Land in ha	
Kidest Hana	69	46	55.25	9.25
Shaga	81	52	58.5	6.5
Shina	57	36	43.75	7.75
Wagetera	91	56.25	65.25	9
Nabega	87	55	62	7

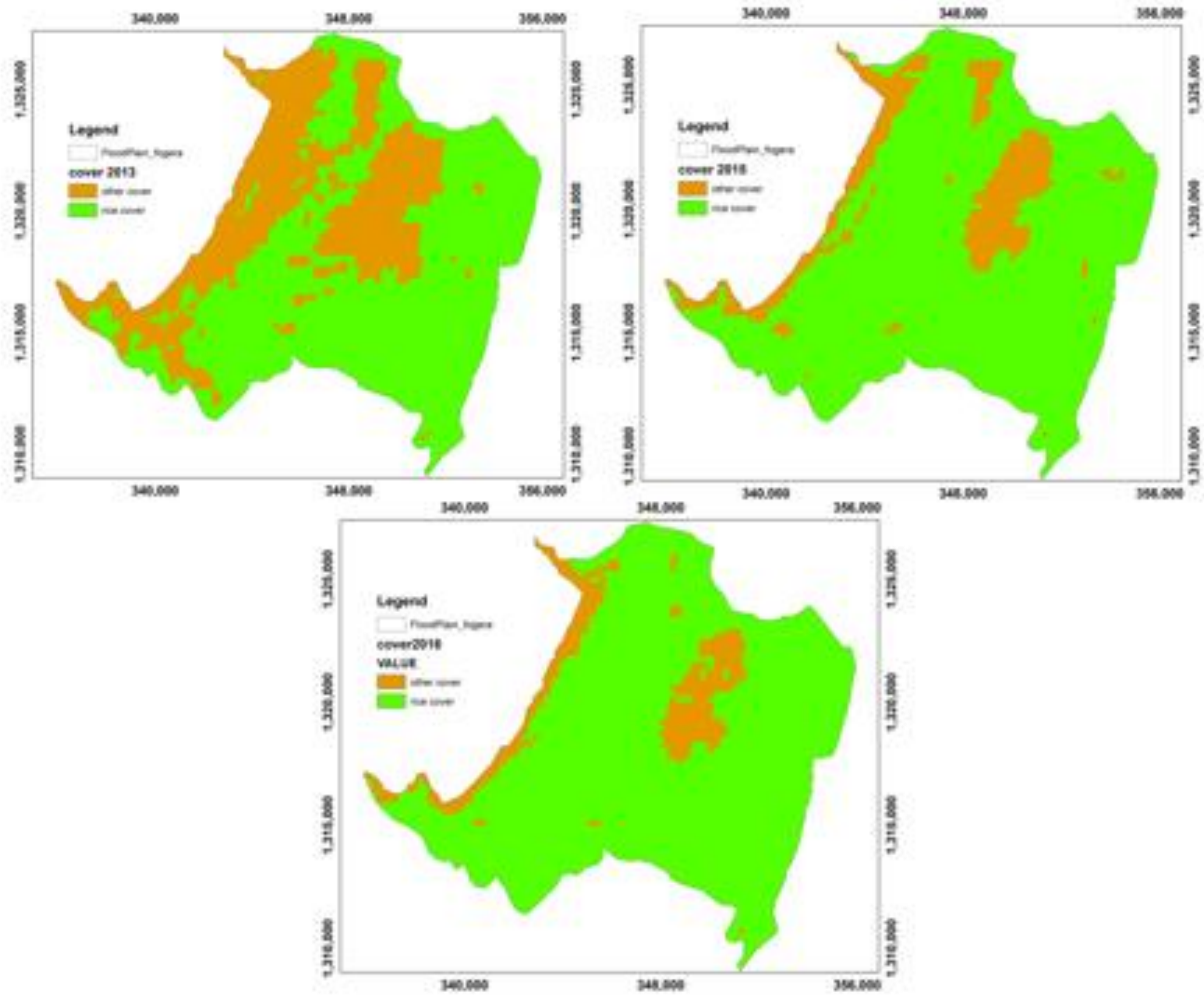


Fig. 4.11 Land-use coverage for rice and other land use for the years 2013, 2015, and 2016

About 89% of the respondents reported that the types of cropping pattern practiced are mono-cropping whereas about 11% of sampled respondents said that they practiced crop rotation (Table 4.9). Those who practiced crop rotation explained they used rotation because their farmland is far away from the floodplain which is located on the uplands.

Table 4.9 Types of cropping pattern

No. of Kebeles	N^{o} Sample Respondents	Mono Cropping	Crop Rotation
Kidest Hana	69	62	7
Shaga	81	69	12
Shina	57	51	6
Wagetera	91	81	9
Nabega	87	79	8

4.1.2.2 Agricultural Inputs Application

The entire respondent group mentioned that the methods to maximize yield are being applied to agricultural inputs such as chemical fertilizer, improved seed, insecticide, and herbicide, resulting in the expansion of rice farming through encroaching wetlands and communal grazing lands (Table 4.10). Insecticide has been used for most crops of chickpea *(Cicer arietinum)* and grass pea *(Lathyrus sativus)* which are relayed after rice *(Oryza sativa)*. Not all respondents used agro-chemical inputs, but rather they used manure for the production of maize *(Zea mays* L.*)* and green pepper (*Capsicum spp.), w*hereas manuring, fallowing, and crop rotation were not applicable for rice in the area (Table 4.10).

Table 4.10 Inputs used for the production of crops

No. of Kebeles	No.of Respondents	Fertilizers	Improved Seed	Using Insecticides	Using Herbicides
Kidest Hana	69	69	69	69	69
Shaga	81	81	81	81	81
Shina	57	57	57	57	57
Wagetera	91	91	91	91	91
Nabega	87	87	87	87	87

About 45.5% of respondents applied fertilizer, and 23% used improved seed. In addition, about 95% of respondents used pesticides, and herbicides were used by about 64% of the respondents (Fig. 4.12). This spraying of pesticides kills insects and those insects are eaten by birds (Fig. 4.13). Therefore, the birds could be affected.

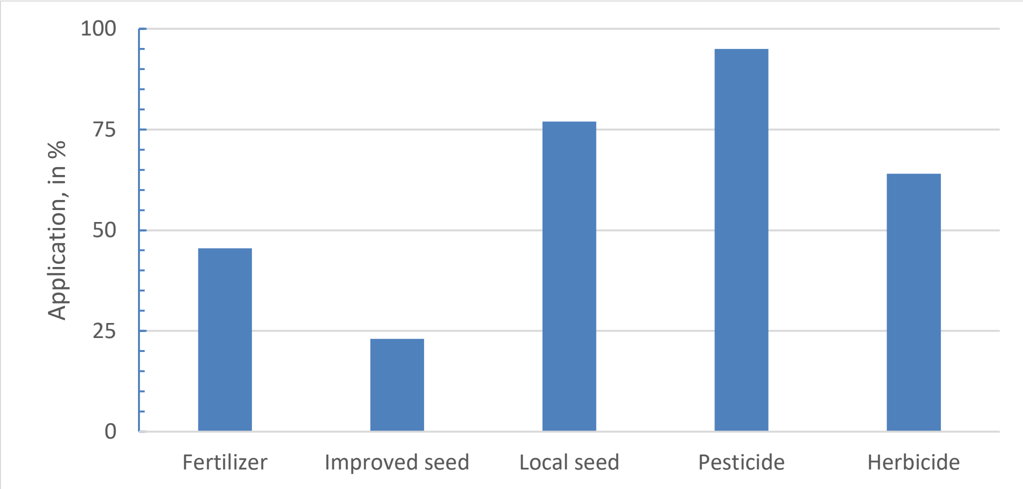


Fig. 4.12 The chemical inputs application for rice in the Fogera floodplain

Fig. 4.13 A farmer spraying pesticide close to birds roosting sites

About 74% of respondents recognized negative environmental effects of using agricultural inputs, including reduced numbers of birds (73%), bee colonies (96%), fish (73%), and other animals such as macro-invertebrates, reptiles, and amphibians (73%) in the wetlands of the study area (Table 4.11 and Fig. 4.13).

Table 4.11 Negative impacts of application of agricultural inputs

Kebele	No.of Respondents	Water Pollution	Reduction of Birds	Reduction of Bees	Reduction of Fish	Reduction of Other Animals
Kidest Hana	69	53	47	55	50	48
Shaga	81	64	63	80	63	63
Shina	57	41	41	57	41	41
Wagetera	91	66	66	91	66	66
Nabega	87	62	62	87	62	62

About 22% of the respondent farmers said that they practice recession farming, i.e., they plant along the shore as water recedes (Fig 4.14 and Table 4.12). After rice is harvested, they tend to plant maize during the dry season. The majority who did not practice recession farming did so because their farms were too far away from receding bodies of water.

Fig. 4.14 Recession farming near Lake Tana and wetlands

Table 4.12 Availability of Recession Farming Practice

No. of Sample Kebeles	Recession Farming		
	No. of Sample Respondents	Yes	No
Kidest Hana	69	11	58
Shaga	81	16	65
Shina	57	8	49
Wagetera	91	25	66
Nabega	87	23	64

All the respondents recognized the effects of the practice on ecosystem services such as papyrus and grass production, bird populations, and the amount and quality of water, including increased siltation and turbidity. However, some farmers were trying to maximize their productivity through the expansion of recession farming at the expense of wetlands and Lake Tana in the study area.

4.1.2.3. Biodiversity

The interviewed farmers and FGD participants have recognized changes they had observed in wetland shrinkage and water resource depletion in their kebele. They observed a reduction in water levels and fish populations, lower papyrus and grass production, fewer birds and hippopotami, and a change in insect populations. Respondents were asked to rank changes in wetland resources. According to their observation, the respondents' problem ranking results indicate that papyrus production was most affected, followed by fish, grass, amount of water, birds, hippopotamus, and sand. Reductions are presented in Table 4.13, and ranked 2^{nd}, 3^{rd}, 4^{th}, 5^{th}, 6^{th}, and 7^{th}, respectively.

Table 4.13 Rank of wetland and Lake Tana resources

Description of Wetland Resources	Resource / Rank	Papyrus	Fish	Sand	Birds	Grass	Amount of Water	Hippopotamus
Wetland resources highly reduced is ranked from the smallest number 1 to the large number 7, e.g., if 1 is selected, the resource is highly reduced.	First = 1	385	0	0	0	0	0	0
	Second = 2	0	135	5	7	191	47	0
	Third = 3	0	43	63	10	95	171	3
	Fourth = 4	0	178	4	117	14	60	12
	Fifth = 5	0	27	30	189	15	71	53
	Sixth = 6	0	1	38	32	28	13	273
	Seventh = 7	0	1	245	30	42	23	44
	Resource / Rank	Papyrus	Fish	Sand	Birds	Grass	Amount of water	Hippopotamus
In this table, the data are the weighted values for each resource responded by sampled respondents, e.g., 385 sampled respondents give rank for each resource.	1	385	0	0	0	0	0	0
	2	0	270	10	14	382	94	0
	3	0	129	189	30	285	513	9
	4	0	712	16	468	56	240	48
	5	0	135	150	945	75	355	265
Rank value *each value given by respondents, e.g., 1*385 = 385 continuous like this.	6	0	6	228	192	168	78	1638
	7	0	7	1715	210	294	161	308
Weighted Sum Total		385	1259	2308	1859	1260	1441	2268
	Rank	1^{st}	2^{nd}	7^{th}	5^{th}	3^{rd}	4^{th}	6^{th}

All of the respondents strongly desire to conserve the wetlands of Fogera and Lake Tana. Perceived benefits included the preservation of papyrus, fish, birds, grass, clean water, reduced flooding, increased soil fertility, wildlife habitat, and vegetation, and reduced land and water degradation. Recession farming is considered as a disadvantage for certain users because respondents linked it to the increasing number of hippopotamuses and birds that damage their crops, and there would be no free fish harvest in the wetlands and the lake (Fig. 4.15).

Fig. 4.15 Fish harvest locally at the Eastern Shore Lake Tana on the border of Fogera floodplain

The diversity of herbaceous vegetation in the three Kebeles of the Fogera floodplain was found to be 2.15, 2.27, and 2.44 for Nabega, Shaga, and Wagetera Kebeles respectively (Table 4.14). The overall average for the floodplain was 2.30. The evenness for the area was 0.80, 0.86, and 0.93 for Nabega, Shaga, and Wagetera Kebeles, respectively. Most of the species identified in the area were found to be weeds that are encroaching on the area because of cultivation (Appendix II). Hence, the evenness exhibited close to one, having many of those diverse weeds, whereas the maximum diversity index for the area was 2.71 and yet not reached by either of the Kebeles (Table 4.14).

Table 4.14 Biodiversity of herbaceous vegetation in three kebeles of Fogera floodplain

	Shannan Wiener index (H’)				Evenness
Kebele	Sample A	Sample B	Sample C	Average	
Nabega	1.91	2.31	2.23	2.15	0.80
Shaga	2.28	2.27	2.26	2.27	0.86
Wagetera	2.46	2.43	2.44	2.44	0.93

4.1.2.4. Hydrological Alteration in the Fogera Floodplain Wetlands

The performance of the SWAT2012 model was found to be R^2 0.61 and NSE 0.60 for calibration and R^2 0.51 and NSE of 0.50 for validation.

4.1.2.4.1. Monthly Flow Trends

The monthly flow analysis indicated that lower flows occur from December to June, the lowest being in April, with a median flow of 0.01 m^3s^{-1}, and higher flows occurring from July to

November, the highest being in August, with a median flow of 94.5 m^3s^{-1} (Fig. 4.16). A high coefficient of variation (COV) of an average of 1.0 was found from November to May during the dry season, and a low COV of an average of 0.5 was observed from June to October during the wet season. Dry monthly flows have an increasing trend in the beginning months, and later months showed a decreasing trend, but rainy season months showed an overall decrease (Fig. 4.17). Flows in the dry season in March and April increased in time likely due to the flow releases from the upstream Ribb Dam during construction time, and from May to September (rainy season) decreased likely due to that the dam holds water.

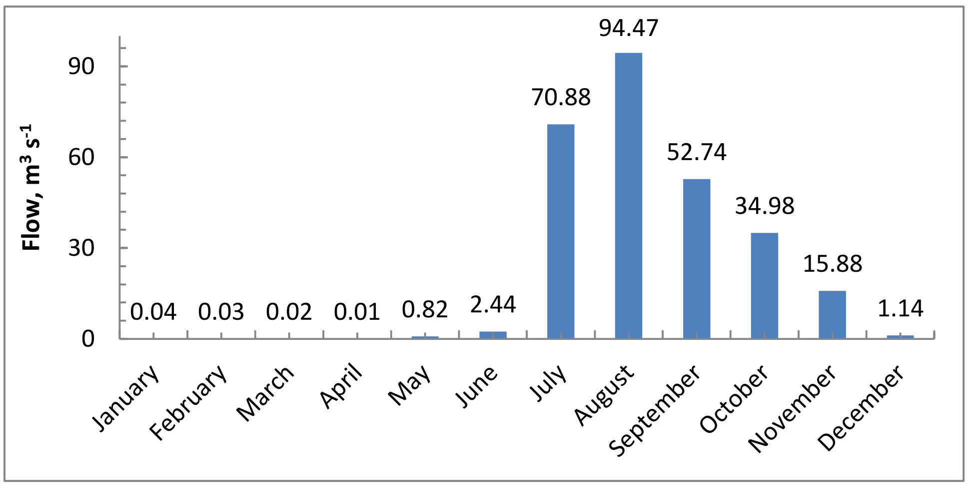
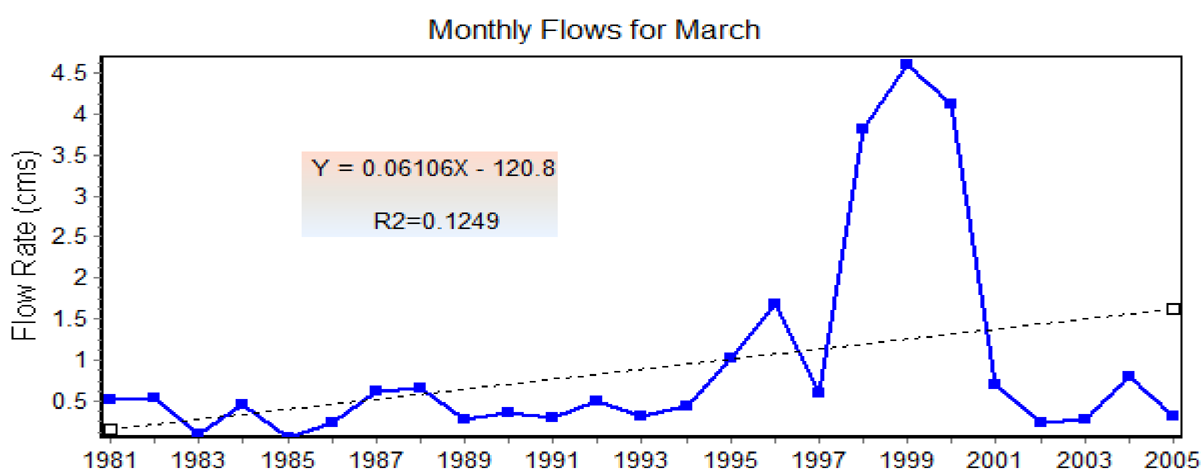


Fig. 4.16 Monthly flow average in m3s−1 of Ribb River from 1981 to 2005



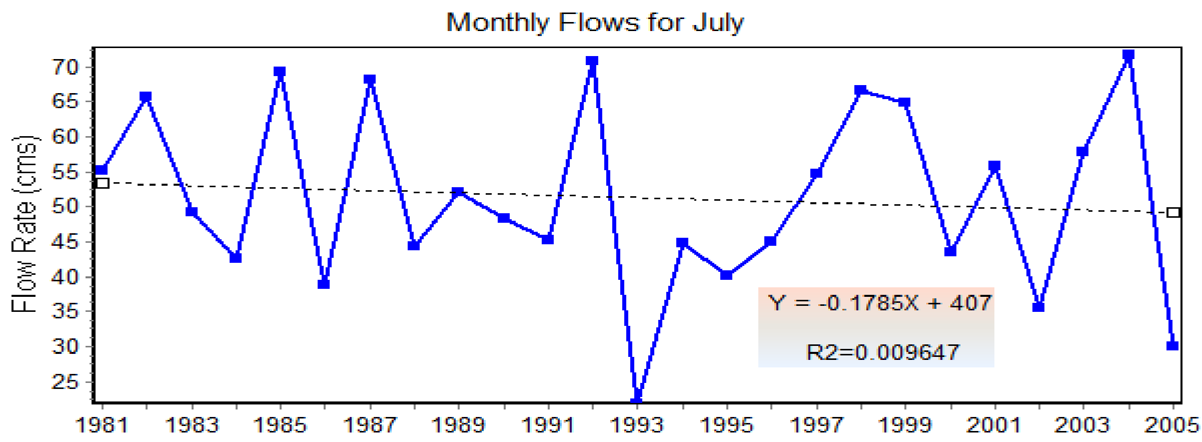


Fig. 4.17 Monthly flow trend of Ribb River between 1981 to 2005

The monthly flow trend of Ribb River between 1981 to 2005 showed that March represents dry season months and July represents rainy season flows. cms-cubic meter per second (Fig. 4.17).

4.1.2.4.2. Water Chemistry

The summary statistics for water flow, Nitrogen, and Phosphorus revealed that Pearson's correlation of water flow with N and P was −0.069 and −0.072, respectively. These have negative relationships, whereas the correlation between N and P has a positive correlation with a value of 0.242 (Table 4.15). Hence, the water quality deteriorates with stream flow decrease.

Table 4.15 Summary statistics for correlation of flow, N and P

Variable	Observations	Obs. with Missing Data	Obs. without Missing Data	Minimum	Maximum	Mean	Std. Deviation
Flow m^3/s	35	0	35	18.670	42.280	31.276	6.134
N m^3/s	35	0	35	0.040	2.830	0.911	0.651
P m^3/s	35	0	35	0.170	0.360	0.261	0.047

Seasonal and annual variations in the hydrological functions of the study wetlands were observed. Hence, in the floodplain, the water level decline has been recognized in the wetlands, where there is a loss of fish, depletion of papyrus and other wetland grass species, and disappearance of the hippopotamus population as well as migratory birds.

Table 4.16 indicates the water quality status of the Welala and Shesher wetlands in the Fogera floodplain from different studies. Note: Shesher 01 and 02 are two sampling points in the wetland where a river comes in and out.

Table 4.16 Water quality status of the Welala and Shesher wetlands of Fogera floodplain

Parameters	Units	Negash *et al.*, (2011)		Abebe *et al.*, (2021)		Simulated Wetland Areas				
		Shesher (2009 to 2010)	Welala (2009 to 2010)	Shesher 01 2020	Shesher 02 2020	2009	2010	2011	2012	2020
Nitrate	mg/l	1.18	1.14	0.349	0.176	2.67	1.23	0.36	1.61	0.32
Phosphate	mg/l	0.54	2	0.443	1.371	0.36	0.2	0.24	0.34	0.05

Aside from better land-use practices, livestock overgrazes and macrophyte overharvesting in the Fogera floodplain play a synergistic role in disrupting the area’s hydrological cycle and microclimate regulation.

4.1.3. The impacts of rice cultivation on an Indigenous Fogera cattle population at the Eastern shore of Lake Tana

4.1.3.1. Crop production

Before large-scale rice production was introduced, the Fogera wetlands used to be flooded during the wet season. Tradition, multiple cropping systems were used and included teff (*Eragrastis tef*), maize (*Zea mays*), noug (*Guizotia abyssinica*), finger millet (*Eleusine coracana*), chickpea, lentil (*Lens culinaris*), and grass pea (*Lathyrus sativus*) (Fogera Woreda Agriculture Office 2015). During the dry season, horticultural crops were cultivated under small-scale irrigation, including mainly onion (*Allium cepa*), garlic (*Allium sativum*), green pepper (*Capsicum* spp.), and tomatoes (*Solanum lycopersicum*).

Rice introduction began in the 1970s with two farmer associations and quickly expanded to 14 kebeles. Data from the Woreda Agriculture Office (Fig. 4.18) showed that over 10 years, the rice crop has become by far the most predominant crop, increasing dramatically, while during this same period, traditional crops decreased. This was also indicated by the primary data collected directly from the sample household (Fig. 4.19) which showed rice production had the highest position compared to the other crops in the areas. The predominance of rice and the relative unimportance of traditional crops are reflected in our 2015 household data as well (Fig. 4.19).

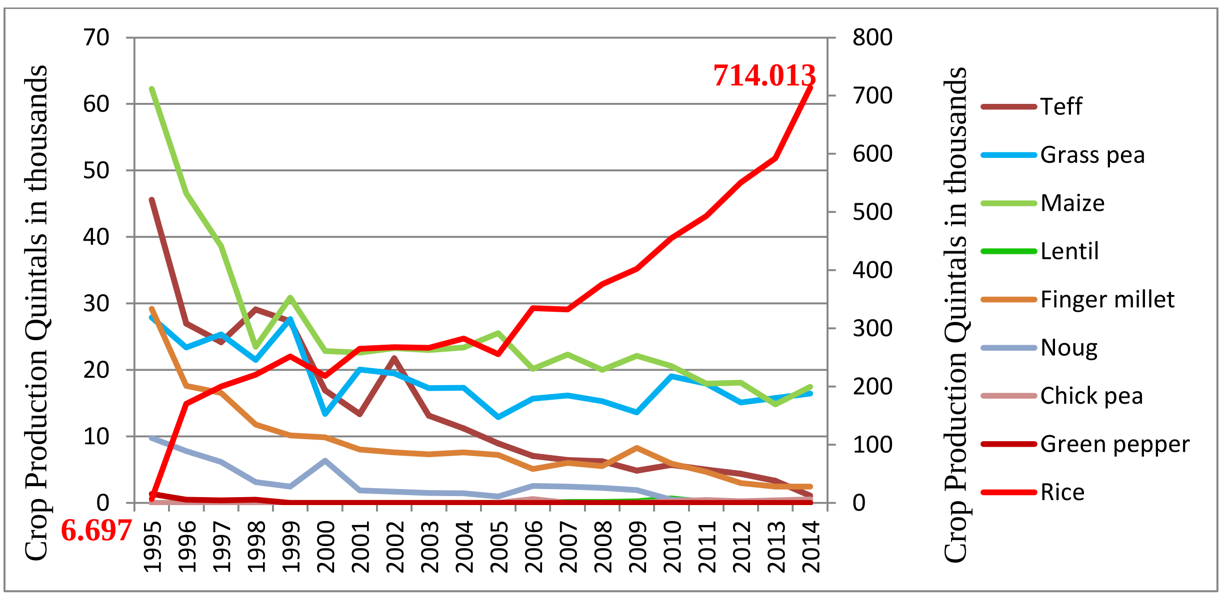


Fig. 4.18 Trends and growth rates of crop production in Quintal from 1995-2014

Fig. 4.18 indicates Trends and growth rates of crop production in Quintal in the study kebeles from 1995 to 2014. Rice production increased while the rest of the crop types were diminishing.

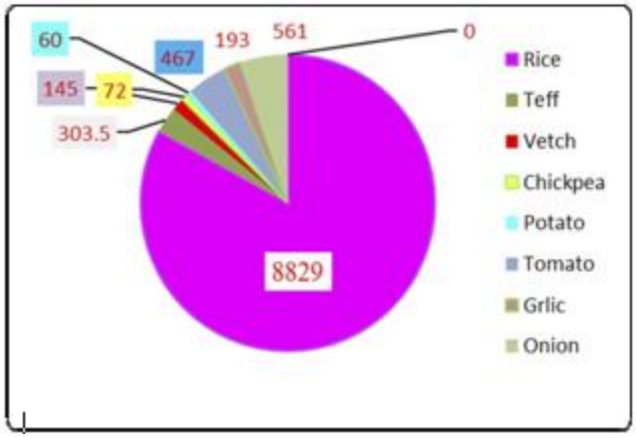


Fig. 4.19 Crop production in quintals in the year 2015 collected from sample household

4.1.3.2. Livestock population

The mean cattle holdings in the study area ranged from four to six animals per household among kebeles in 2015 (Fig. 4.20). Relatively, Kidest Hana kebele farmers hold the better number of livestock per household (6.15). Survey data suggest that the total number of cattle in all five kebeles steadily decreased over the last 20 years (Fig. 4.21). The study also revealed that there was ~ 21% decline in cattle population from 2005 to 2014. On the contrary, the study also noted a concomitant increase in the number of sheep, donkeys, mules, and poultry over the same period. In addition, analysis of livestock units and checking of homogeneity of variance have been made (Table 4.17).

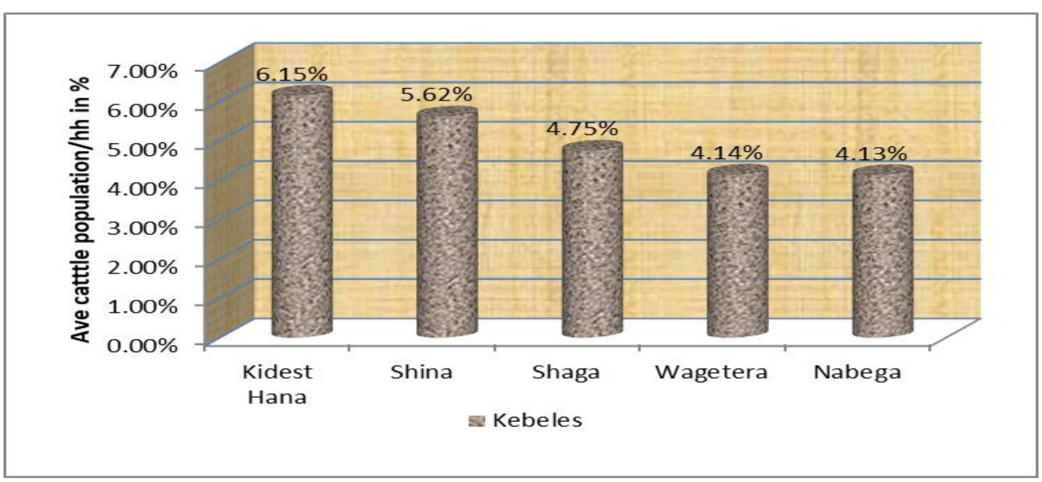


Fig. 4.20 Average cattle per household for sample kebeles

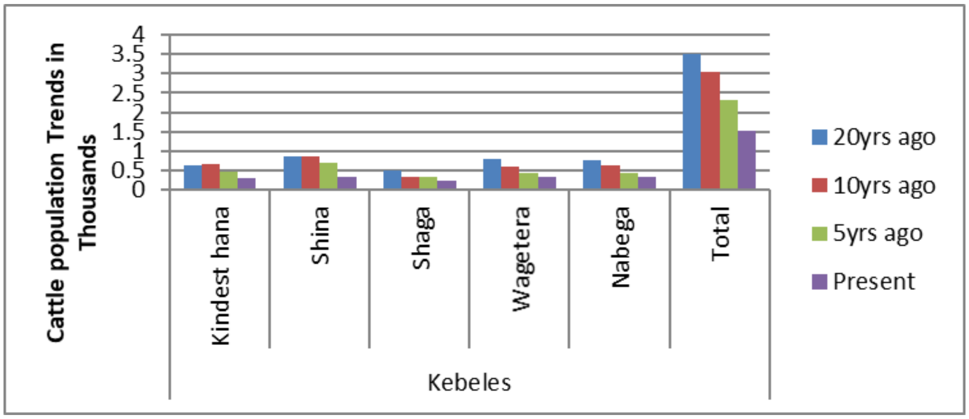


Fig. 4.21 Mean cattle number per household summed over five kebeles in the Fogera district

Table 4.17 indicates least squares means for effect kebele (part a) and least squares mean comparisons among kebeles (part b). Analysis of variance (ANOVA) was also used to analyze livestock units of the sample kebeles. The LEVENES test was used to check the homogeneity of variance.

Table 4.17 Least square means for effect kebele

Kebele**	1	2	3	4	5	SEM
LSM of TLU	0.168^{ab*}	0.170^{ab}	0.216^{a}	0.161^{b}	0.127^{b}	0.019

*Means in the same row with different superscript are different at P < 0.05

**1 = Kidest hana, 2 = Shina, 3 = Shaga, 4 = Wagetera, 5 = Nabega

Kebele 3 was significantly different from kebele 4 and 5, and no significant difference was observed between kebeles 1, 2, and 3 (Table 4.17b). Kebeles 1, 2, 4, and 5 had no difference (P > 0.05) in TLU per household.

(a) Kebele Least squares mean Standard error pr > t

1	0.1682	0.0173	< 0.0001
2	0.1702	0.0159	< 0.0001
3	0.2163	0.0190	< 0.0001
4	0.1613	0.0150	< 0.0001
5	0.1275	0.0154	< 0.0001

(b) Kebele

	1	2	3	4	5
	1	0.9323	0.0622	0.7660	0.0807
	2	0.9323	0.0643	0.6876	0.0558
	3	0.0622	0.0643	0.0242	0.0003
	4	0.7660	0.6876	0.0242	0.1183
	5	0.0807	0.0558	0.0003	0.1183

Table 4.18 Available feed and number of respondents on feed source usage

Kebele	Communal land	Purchased hay	other crop residues	Rice residue
Kidest hana (N = 69)	68 (98.6%)	32 (46.4%)	22 (31.9%)	68 (98.6%)
Shna (N = 81)	81 (100%)	8 (9.9%)	22 (31.9%)	81 (100%)
Shaga (N = 57)	57 (100%)	13 (22.8%)	23 (40.4%)	57 (100%)
Wagetera (N = 91)	91 (100%)	27 (29.7%)	24 (26.4%)	91 (100%)
Nabega (N = 87)	87 (100%)	33 (37.9%)	26 (29.9%)	87 (100%)
Total	384 (99.7%)	113 (29.4%)	127 (34%)	384 (99.7%)

4.1.3.2.1. Animal feed

The feed resources of livestock in Fogera wetland areas consisted of uncontrolled communal grazing lands, purchased hay, rice crop residues, and other crop residues. In the study kebeles, out of 385 respondents, 99.7% of them used both free grazing communal lands and rice crop residue as the main feed source for their livestock. In addition, 29.4% of respondents buy hay from neighboring farmers, and 34% use other crop residues or rice residue as feed sources for their livestock (Table 4.18).

4.1.3.2.2. Feed dry matter supply

A total of ~ 45 tons of feed dry matter (DM) were produced from crop residue and natural pasture across the sampled kebeles (n = 385) (Table 4.18). Total dry matter yield, which was estimated from grazing pasture and crop residues, is presented in Table 4.19. Data indicate much larger dependence on crop residue (99.89%) for feed than on grazing land (0.11%). Overall, available feed in terms of dry matter per annum was only ~ 60% of that needed to meet household TLU feed requirements. Yet, ~ 40% of dry matter per annum was required to meet the existing TLU requirement (Table 4.19). All dry matter was calculated for the present cropping system.

4.1.3.2.3. Traditional grazing system in the study wetland areas

When the main available feed resource was communal grazing land, animals were fed through a communal grazing system which caused overgrazing problems and unwanted breeding. The sample households were asked whether they used alternative grazing management systems for communal lands, such as cut and carry, or rotational grazing. Households with livestock responded anonymously that they used only a free grazing system.

Table 4.19 Animal feed supply and requirement in tons of dry matter (DM)

kebele	Rice resi	Teff resi	cp resi	cp resi	GL kg/hh	TDM resi	TDM Yield	Total TLU	Required TLU	per hh Required	Difference
Kidest hana	301,990	21,150	17,520	0	320	340,980	13.539	185.1	1156.875	16.766	− 3.227
Shina	248,820	7875	10,320	360	400	267,775	9.057	207.9	1299.375	16.041	− 6.984
Shaga	140,270	5550	5520	0	240	151,580	7.285	131.9	824.375	14.462	− 7.177
Wagetera	243,620	4200	6600	0	100	254,520	7.662	195.9	1224.375	13.454	− 5.792
Nabega	213,070	6750	7200	8280	265	235,565	7.418	191.5	1196.875	13.757	− 6.339
Total	**1,147,770**	**45,525**	**47,160**	**8640**	1325	**1,250,420**	**44.961**	**912.3**	**5701.875**	**74.48**	**− 29.519**
	Gp grass pea, Cp chickpea, GL grazing land per household, TDM total dry matter, Resi residue										

4.1.3.3. Annual income gained

The household farming activities in the study kebeles were crop production, livestock rearing, horticulture, beekeeping, and fishing. Rice production contributed 84.8% of total income, clearly the lion's share. There were modest differences among the kebeles for percentages of income originating from other crops (Table 20). According to the respondents, the most important factors determining their annual average incomes were the landholding size, fertility of the farmland, availability of flood water, management practices of the individual farmer, and amount of livestock holding.

Table 4.20 Annual incomes of the sample household in the surveyed sample kebeles

Kebele	Respon	Rice	%	Animals	%	other crop & sources	%	Total	Ave?hh
Kides H	69	2508800	89	33,800	1.2	276,820	9.8	2,819,420	40,861.20
Shina	81	2093300	87.8	10,750	0.5	279,325	11.7	2,383,375	29,424.40
Shaga	57	1192600	83.6	5344	0.4	228,870	16	1,426,814	25,031.80
Wagetera	91	2056800	78.8	6066	0.2	546,804	21	2,609,670	28,677.70
Nabega	87	2927500	84.3	6340	0.2	537,340	15.5	3,471,180	39,898.60
Total	385	10779000	84.8	62,300	0.5	1,869,159	14.7	12,710,459	33,014.20

Note: Income in Ethiopian birr (in 2015)   Repon = Respondents

Table 4.21 The response of farmers on the effect of rice production on Fogera cattle population reduction

Kebele	Number	Yes	No
Kindest hana	69	61 (88.4%)	8 (11.6%)

Shina	81	66 (81.5%)	15 (18.5%)
Shaga	57	47 (82.5%)	10 (17.5%)
Wagetera	91	75 (82.4%)	16 (17.6%)
Nabega	87	75 (86.2%)	12 (13.8%)
Total	385	324 (84.2%)	61 (15.8%)

4.1.3.3.1. Livestock Income

Income from livestock contributed a mere 0.5% on average among kebeles, and that was significantly less than the income from rice (84.8%) and other crops (14.7%) (Table 4.21). A focus group consisting of animal science experts concurred that farmers now pay less attention to livestock rearing, preferring instead to focus on rice production because of high grain prices (1100.00 Ethiopian birr per quintal in 2015). Livestock production was restricted because of limited forage and grazing lands. Together, these trends explain the gradual loss of indigenous livestock numbers.

4.1.3.3.2. The effect of rice production on Fogera indigenous livestock population

According to the five animal science experts (development agents), the mean rice yield was estimated at 35 qt/ha and ranges from 20 to 80 qt/ha depending on the land type and management practices. According to the Woreda Agricultural Office expert, still, there is a potential to expand rice production to 28,000 ha of land. Rice straw is used as animal feed and for roof thatching.

Even though Fogera district was dominantly characterized by a mixed crop-livestock subsistence farming system, the extent of crop and livestock integration varied farmers' attitudes toward rice production and less attention to their cattle because of grazing land problem, according to 84.2% of sample respondents' explanation, rice farming has caused a reduction of Fogera indigenous cattle population. Approximately 15.8% claimed that rice production had not caused a reduction in cattle numbers, but the panel of experts claimed this was because many of the 16% were using land illegally for rice production. All respondents agreed that the number of pure-breed Fogera cattle was declining over time (Table 4.21). Currently, pure Fogera cattle breeds are found only in small numbers in the villages of Sindeye, Tigre mender, and Damote. In other kebeles, where the breed used to be common, there was an unwanted crossbreeding with other indigenous breeds such as the Estie, Dera, and Fareta during communal grazing in the Fogera plains.

Increased rice crop production is negatively correlated with cattle population (Fig. 4.22). The correlation value of − 0.889** was significant at the $P < 0.01$. Rice crop production has gained more interest among farmers because of its potential to generate income. But increased income comes apparently at the cost of its indigenous cattle population and other wetland resources.

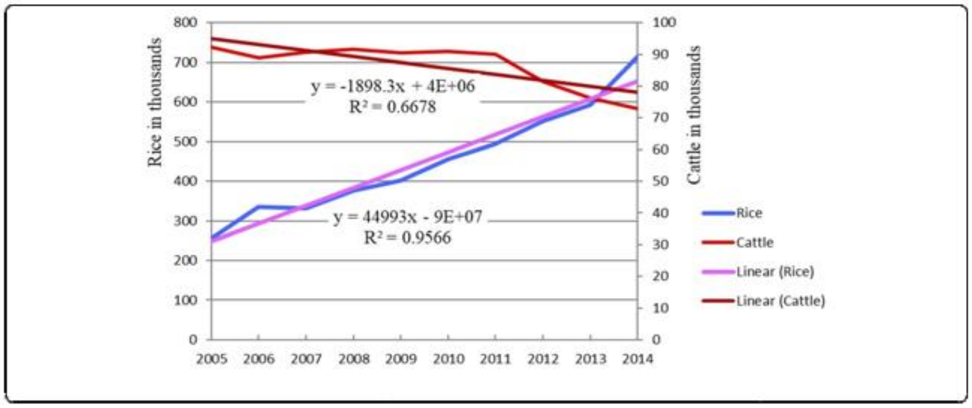


Fig. 4.22 Trends of cattle population and rice production

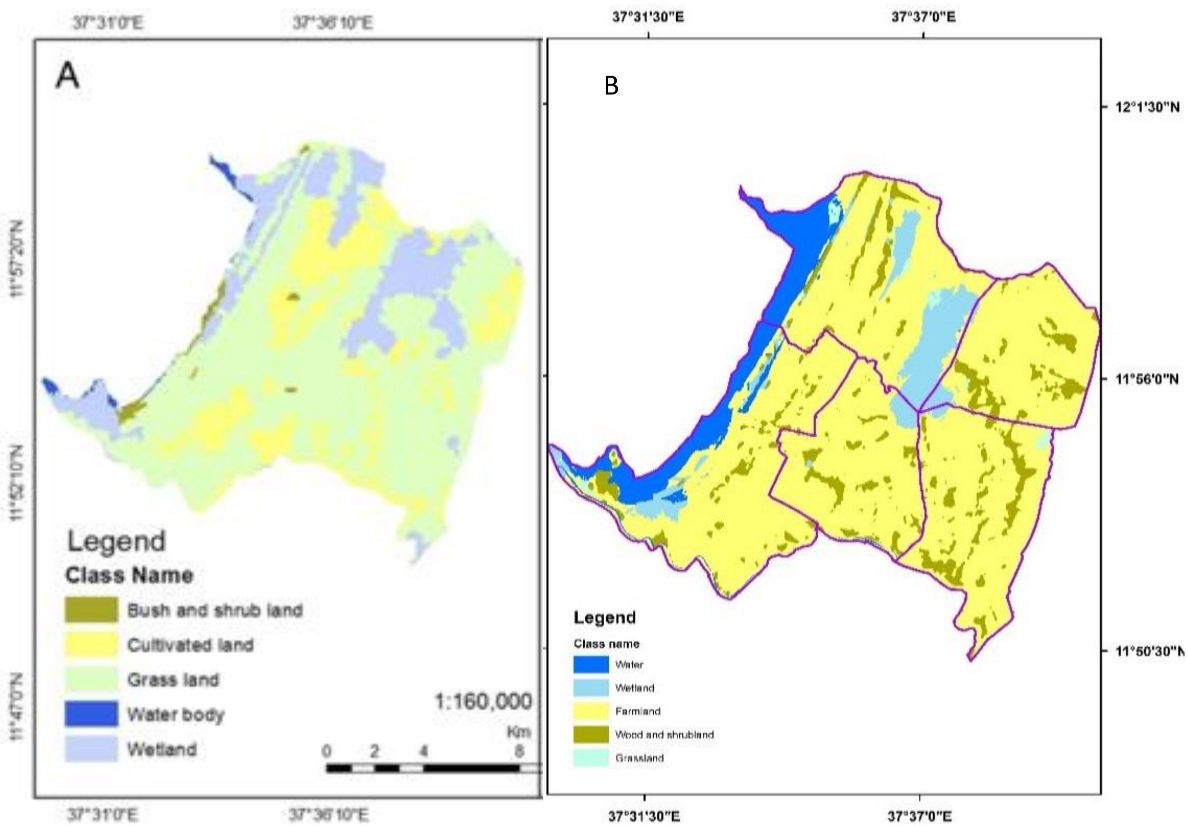


Fig. 4.23 Land use/land cover map of the study site

Fig. 4.23 Land use/land cover map of the study site. A and B is the land use/land cover maps of year 1973 and 2021, respectively. The classification results for 1973 and 2021 are summarized in

(Table 4.22). The percentage of classes based on these results showed the land use/land cover practices observed in the study area between 1973 and 2021

Table 4.22 Land use/land cover classes and areas in hectares

Class name	1973	percent	2021	percent	2021-1973
Agriculture land	3440.6	20.1	12735.9	74.3	9295.3
Forest land	1542	9.0	1567.93	9.1	25.93
Grazing land	8549.5	49.9	126.93	0.7	-8422.57
Wetland	3113.9	18.2	1245.52	7.3	-1868.38
Water body	501.9	2.9	1470.6	8.6	968.7
Total	17147.9	100.0	17147.9	100.0	0

Source: Generated from Landsat image classification

4.1.3.3.3. Grazing land reduction detection

The correlation trends indicated in Fig. 4.23 were further supported by land-use changes illustrated in (Fig. 4.24). Grassland areas were greatly reduced in favour of cultivated rice between 1973 and 2021 (Fig. 4.24). Other declines were observed in wetlands. At the same time, the area under water and forest slightly increased. Quantitative comparisons for changes in land use were shown in (Table 4.22 and Fig. 4.24). Specifically, grazing lands were reduced from 8550 ha or 50% of land area to 126.93 ha or 0.7%% of land area, wetlands from 3114 ha or 18% of land area to 1245.52 ha or 7.3% of land area, and forestlands from 1542 ha or 9% of land area to 1567.93 ha or 9.1% of land area. Concurrently, cultivated land area increased from 3441 ha or 20% of land area to 12735.9 ha or 74.3% of land area, and water surface area from 502 ha or 3% of the study area to 1470.6 ha or 8.6% of the area.

The confusion matrix was also done for the accuracy assessment generated from the land use land cover classification (Table 4.23).

Table 4.23 Radon forest confusion matrix for accuracy assessment

	Range land	Forest	wetland	Farmland	buildup	Water body
Range land	20	0	0	0	0	0
Forest	0	87	0	0	0	0
wetland	0	0	30	0	0	0
Farmland	0	0	0	50	0	0
builtup	0	0	0	0	52	0

Water body	0	0	0	0	0	30

Previous to the massive introduction of rice production, the borderline of Lake Tana that was covered by papyrus and long grass has been cleared out now, exposed to sunlight, and visible for remote sensing, respectively. The area was covered by vegetation such as reeds, *Butia capitata* (palm tree), long grasses, and papyrus; but nowadays, the vegetation has been removed around the border of the lake because of recession farming and for the dry season small-scale irrigation due to population dynamics (Fig. 4.25).

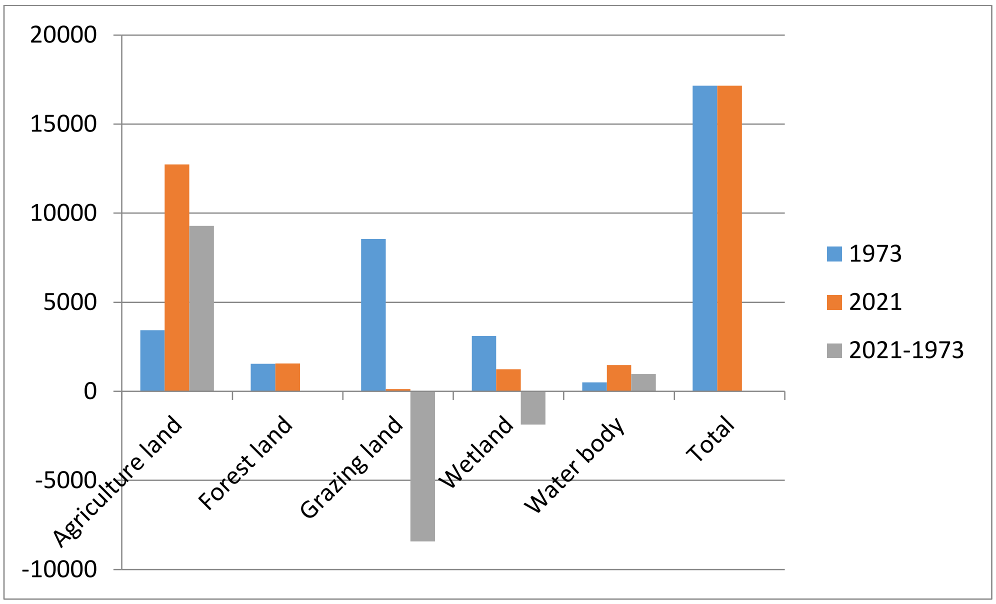


Fig. 4.24 Land use/land covers change of the study site map in the year 1973 and 2014

Fig. 4.25 Practice of small-scale irrigation in the wetlands of Fogera and birds' interaction

4.1.4. Impact of Rice Expansion on Traditional Wetland Management in the Fogera Wetlands

4.1.4.1. Market Information and Participation in Rice Production

The farming production system was changing because of the better market price of rice, second to teff (*Eragrostis tef*), according to all of the respondents. Rice became a dominant crop in the study area, while crops such as green pepper (*Capsicum* spp.), maize *(Zea mays* L.*)*, noug (*Guizotia abyssinica*), and finger millet (*Eleusine coracana*) were almost out of production, except in small pocket localities of the study area.

A total of 87% of the farmers participated in the rice markets, where they sold portions of their rice produce, whereas 13% of the respondents used the rice for household consumption (Table 4.24).

Table 4.24 Farmers' participation in the rice market in Fogera Woreda

Kebele	No of Respondents	Yes	%	No	%
Kidest Hana	69	68	98.5	1	1.5
Shina	81	73	90.1	8	9.9
Shaga	57	48	84.2	9	15.8
Wagetera	91	76	83.5	15	16.5
Nabega	87	70	80.5	17	19.5
Total	385	335	87	50	13

Farmers were motivated to produce more rice than other crops because of high price and demand; market price was 63%, consumer demand 20.5%, and demand for rice seed 15.9% (Table 4.25). Therefore, market forces were driving factors for the farmers to produce more rice than other crops.

Table 4.25 Motivating factors for farmers to produce more rice in the Fogera floodplain

Kebele	No of Respondents	Consumer Demand	Demand for Rice Seed	Market Price of Rice
Kidest Hana	69	13 (18.8%)	8 (11.6%)	48 (69.6%)
Shina	81	16 (19.8%)	12 (14.8%)	53 (65.4%)
Shaga	57	11 (19.3%)	6 (10.5%)	40 (70.2%)
Wagetera	91	21 (23.1%)	19 (20.9%)	51 (56%)
Nabega	87	18 (20.7%)	16 (18.4%)	53 (60.9%)
Total	385	79 (20.5%)	61 (15.9%)	245 (63.6%)

Regarding the supply of rice grain, 94.5% of the sampled households responded that there was not enough rice in the market; thus, conversely, 5.5% said there was enough rice in the market (Table 4.26). This situation encouraged farmers towards the expansion of rice farming.

Table 4.26 Farmers' understanding of the supply of rice in the market

Kebele	No of Respondents	Enough Supply of Rice for Market	
		Yes	**No**
Kidest Hana	69	4 (5.8%)	65 (94.2%)
Shina	81	3 (3.7%)	78 (96.3%)
Shaga	57	5 (8.8%)	52 (91.2%)
Wagetera	91	5 (5.5%)	86 (94.5%)
Nabega	87	4 (4.65)	83 (95.4%)
Total	385	21 (5.5%)	364 (94.5%)

Becoming informed on the market demand for their crop was necessary for farmers to produce more rice. Farmers are aware of the market demand for rice crops. Respondents (96.4%) agreed that there was a high demand for rice in the market center of the Woreda; whereas 3.6% said there was no demand for rice in the market center of the Woreda (Table 4.27). This motivated farmers to expand and intensify rice farming practices rather than using previous practices.

Table 4.27 Farmers' awareness of rice market demand in the study kebele

Kebele	No of Respondents	Awareness of Market Demand for Rice	
		Yes	No
Kidest Hana	69	69 (100%)	0
Shina	81	78 (96.3%)	3 (3.7%)
Shaga	57	52 (91.2%)	5 (8.8%)
Wagetera	91	89 (97.8%)	2 (2.2%)
Nabega	87	83 (95.4%)	4 (4.6%)
Total	385	371 (96.4%)	14 (3.6%)

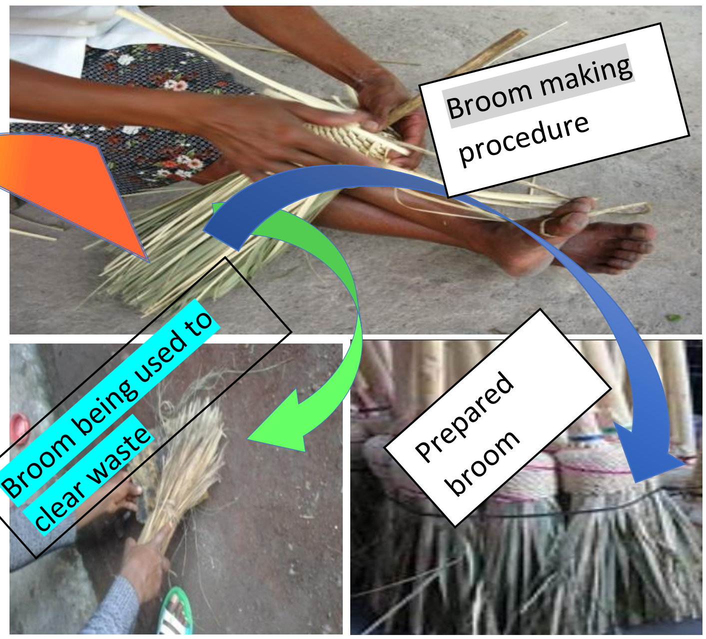
The general consensus of the farmers was the need for an improved rice marketing system. The system should encourage farmers throughout wetland kebeles to participate in rice production, provide access to rice threshing machines for all farmers (villages), enhance infrastructure (roads), improve the variety of rice, and ensure good market linkage in the input–output systems.

4.1.4.2. The Impacts of Rice Price on Traditional Wetland Management Practices

The traditional practices referred to in this study are those that the farmers were previously practicing in the wetland areas. These activities are agricultural activities, such as maize (*Zea mays* L.*)* and green pepper (*Capsicum* spp.) production using livestock manure, the production of noug (*Guizotia abyssinica*) in the floodplains, and fish harvesting in the wetlands (floodplain). Wetland communities used pastures in recently flooded areas for cattle grazing, and forest and bushland were common in floodplains, which were being used as a source of fuel wood. According to the Nature and Biodiversity Conservation Union (NABU) experts and FGD participants, the elderly people had indigenous knowledge of using wetland resources, such as papyrus, reeds, brooms, and *Butia capitata*, for different purposes (Fig. 4.26).

The indigenous knowledge-based activities were once practiced by local people. According to respondents (61.6%), traditional wetland management practices were influenced by the rice market, as the increase in the prices of rice grain led to departures from traditional agricultural practices; additionally, 25.7% of the respondents said the prices of rice almost eliminated the traditional practices in the study area. In contrast, 4.2% of the respondents said that trends in the price of rice encouraged farmers to preserve their traditional practices, and about 12.7% of the respondents were not sure of what counts as traditional knowledge/practice in the study areas (Table 4.28, Fig. 4.26).

Types of traditionally produced goods and harvesting of items	Price (Birr (ETB))/piece
Local boats made from the stem of papyrus	ETB 600 to 1200 (price varies according to its size). 
Use of papyrus leaves during a ceremony	 
"Senele" (*Butia capitata*) for a mat	

<table>
<tr><td>"Senele" (Butia capitata) for a raincoat</td><td rowspan="8">Leaf of papyrus prepared to sell for ceremonial purposes.
All these items are not found at this time because they have been lost from the wetland and respondents have forgotten their price.
The reason for their loss is because of the expansion of rice agriculture in Lake Tana and the wetlands.
Above is a mat made from Butia capitata.


A broom made from the stem of Butia capitata</td></tr>
<tr><td>"Senele" (Butia capitata) for a hut</td></tr>
<tr><td>"Senele" (Butia capitata) used to cover the deceased during burial</td></tr>
<tr><td>Papyrus roof thatching</td></tr>
<tr><td>Papyrus for a mat</td></tr>
<tr><td>Papyrus for home campus fence</td></tr>
<tr><td>Reeds (for rope)</td></tr>
<tr><td>Brooms

</td></tr>
<tr><td>Fishing locally</td><td> ETB 20/kilogram in 2015</td></tr>
<tr><td></td><td>
Traditional fishing traps made from stem of papyrus</td></tr>
</table>

Use of papyrus leaves during a coffee ceremony	 A coffee ceremony
 *Butia capitata* used for making	 Hut  Baggage  sleeping material
Reeds used for a raincoat	 currently, it is not practiced in the area. The younger group didn't know how to make it.

Fig. 4.26 Types of Traditional Goods

Table 4.28 The influence of the rice market on traditional practice/knowledge

Kebele	Respondents (N)	Impacts of Increase in Rice Grain Prices				
		Encourages and Preserves Traditional Practices/ Knowledge	Encourages Promote Traditional Practices/ Knowledge	Hinders Traditional Practices/ Knowledge	Leads to Abandonment of Traditional Practices/ Knowledge	No Change
Kidest hana	69	4 (5.8%)	1 (1.5%)	61 (88.4%)	3 (4.3%)	0
Shina	81	4 (4.9%)	5 (6.2%)	49 (60.5%)	20 (24.7)	3 (3.7%)
Shaga	57	3 (5.3%)	4 (7.0%)	32 (56.1%)	13 (22.8%)	5 (8.8%)
Wagetera	91	2 (2.2%)	4 (4.4%)	50 (54.9%)	31 (34.1%)	4 (4.4%)
Nabega	87	3 (3.4%)	5 (5.8%)	45 (51.7%)	32 (36.8%)	2 (2.3%)
Total	385	16 (4.2%)	19 (4.9%)	237 (61.6%)	99 (25.7%)	14 (3.6%

4.1.4.3. Farmers' Understanding of Traditionally Produced Goods from Wetland Resources

After the introduction of rice, 26% of the respondents claimed that there were traditionally produced goods from wetland resources and the surrounding Lake Tana areas, whereas 74% of the respondents stated that there were no goods produced traditionally from wetland resources during this study (Table 4.29).

Table 4.29 Traditionally produced goods from wetland resources

Kebele	No. of Respondents	Yes	No
Kidest hana	69	6 (8.7%)	63 (91.3%)
Shina	81	14 (17.3%)	67 (82.7%)
Shaga	57	10 (17.5%)	47 (82.5%)
Wagetera	91	32 (35.25)	59 (64.8%)
Nabega	87	38 (43.75)	49 (56.3%)
Total	385	100 (26%)	285(74%)

4.1.4.4. Local Peoples' Perception on Wetland Functions and Services

According to the farmers' explanations, the functions and services of wetland resources were available in the past, but they have been reduced over time (Table 4.30). Respondents also mentioned that the reduction in and loss of these wetland resources are not only depriving the community but also contributing to the loss of their traditional practices. Loss of traditional practices is attributed to rice expansion occurring at the expense of wetland resources.

Table 4.30 Ecosystem services provided by or derived from wetlands that benefit human well-being

Wetlands Services Benefiting Human Well-Being	Services	✔ * X
	Production of fish, fruits and grains, freshwater	*
	Storage and retention of water for domestic and agricultural use	*
Provisioning	Fiber and fuel wood	*

	Extraction of medicines and other materials from biota	X
	Ornamental species	X
	Fodder for indigenous Fogera cattle	*
	Papyrus “Senele” (*Butia Capitata*)	X
Regulating	Climate regulation, e.g., temperature, precipitation	*
	Water regulation (hydrological flows); groundwater recharge/discharge	*
	Water purification and waste treatment retention, recovery, and removal of excess nutrients and other pollutants	*
	Retention of soils and sediments (in floodplain area)	✔
	Natural hazard regulation, flood control, storm protection (flood is required by farmers for rice production	✔
	Pollination habitat for pollinators (e.g., bees)	X
Cultural	Recreational opportunities for recreational activities	
	Many people find beauty and aesthetic value in aspects of wetland ecosystems	*
	Educational opportunities for formal and informal education and training	*
Supporting	Soil formation, sediment retention, and accumulation of organic matter	*
	Nutrient cycling storage, recycling, processing, and acquisition of nutrients	*

Symbols: ✔ = available, * = reduced, X = lost.

Regarding hydrologic function, respondents explained that the whole study area is inundated during the summer season with floodwater from the uplands. Therefore, the floodplains are very important for the farmers to produce more rice. However, they also mentioned that the level of water in the floodplain (wetlands) has dropped compared to past levels. Thus, the hydrologic functions of the wetlands varied seasonally (Fig. 4.27). The frequencies of extremely low flow, small floods, and large floods have all shown a decreasing trend (Fig. 4.28). Trends were tested with a Mann–Kendall trend test, and were found to be significant at p =0.02 for extremely low flow, and p =0.5 for small and large floods (Fig. 4.28). Therefore, there has been a hydrological alteration of the wetland/floodplain areas, especially regarding the low flows, which has led to the disruption of normal hydrologic functions and services.

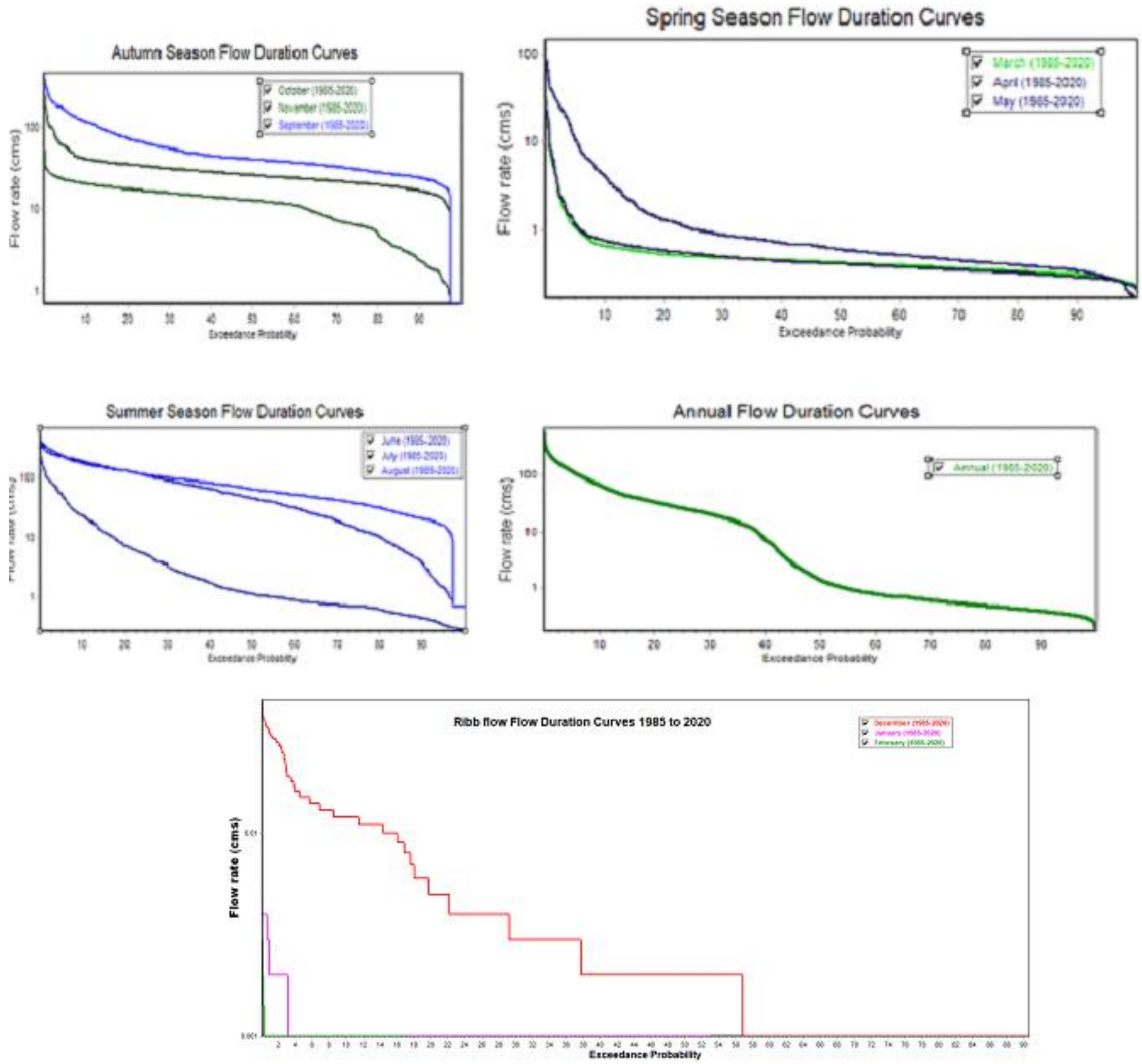


Fig. 4.27 Seasonal and annual flow duration curves

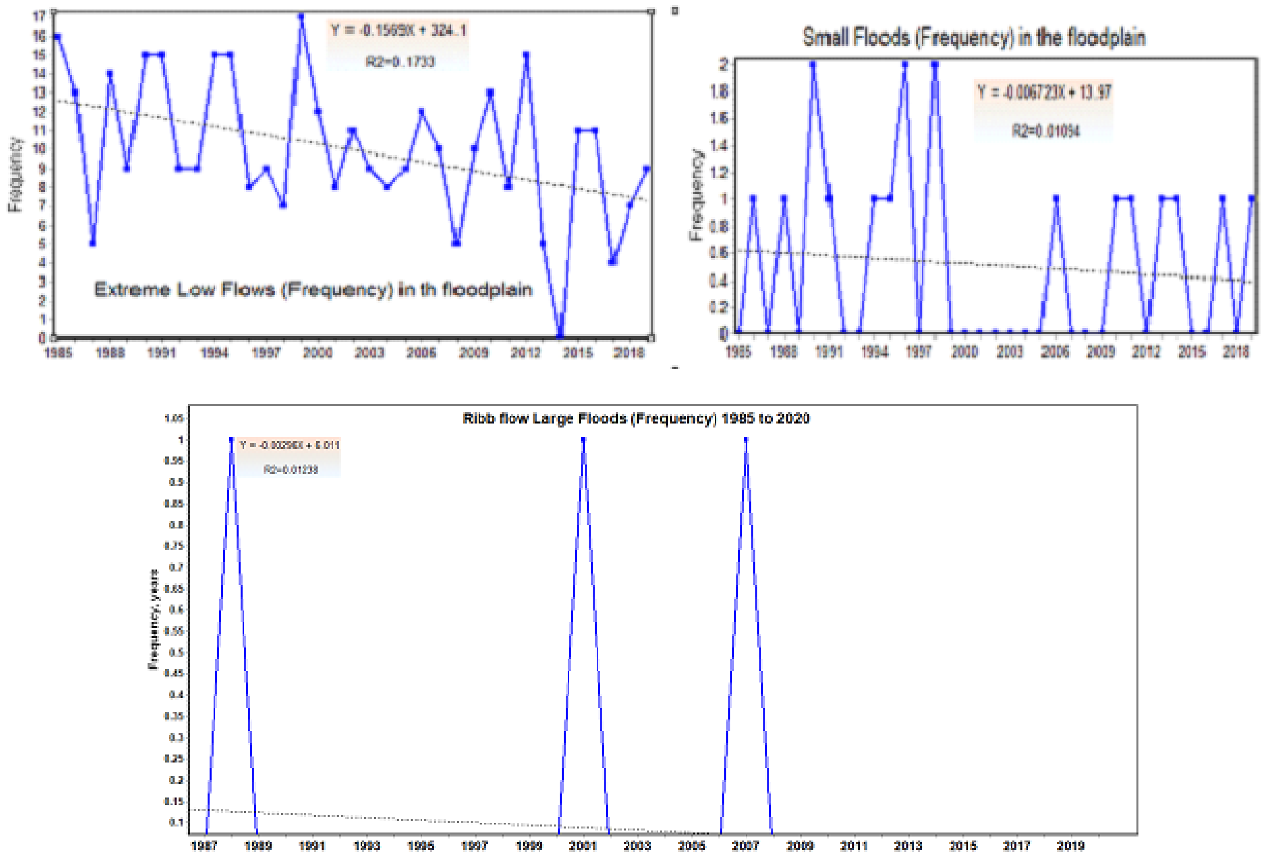


Fig. 4.28 Extreme low flow, small flood, large flood

Note: Fig. 4.28 indicates Extreme low flow, small flood, and large flood frequencies (in days for extreme low flow and years for small and large floods).

4.1.4.5. Farmers' Perception of the Effects of Rice Market on Wetland Resources

A total of 57.9% of the respondents strongly agreed that the increase in the market price of rice has had negative effects on traditional wetland resources management; 34.6% of the respondents agreed, and 7.5% were undecided (Table 4.31), and a further 7.5% abstained. Overall, 92.5% of the respondents said that rice price affects wetland resources in the study area.

Table 4.31 Farmers' Perception on the effects of the rice market on wetland resources

Kebele	Respondents	Strongly Agree	Agree	Neither Agree Nor Disagree
Kidest Hana	69	45 (65.2%)	19 (27.5%)	5 (7.3%)
Shina	81	48 (59.3%)	27 (33.3%)	6 (7.4%)
Shaga	57	31 (54.4%)	23 (40.4%)	3 (5.2%)
Wagetera	91	50 (54.9%)	33 (36.3%)	8 (8.8%)
Nabega	87	49 (56.3%)	31 (35.6%)	7 (8.1%)

Total	385	223 (57.9%)	133 (34.6%)	29 (7.5%)

4.1.4.6. Farmers' Willingness to Support the Efforts of the Nature and Biodiversity Conservation Union

It was found that 57.1% of the respondents demonstrated a willingness to support the efforts of the NABU to implement the biosphere reserve principles in their kebeles (Table 4.32). Another 13.5% of the respondents indicated that they were not willing to support the efforts of the NABU, whereas 29.4% of the respondents did not know anything about the program. About 70.6% of the respondents receive information about the efforts of NABU.

The unwillingness of some of the respondents may be due to fear of a legal framework that would not allow them to illegally encroach on the wetlands or communal grazing lands to expand rice farming. During the promotion of any development activities, the participation of local farmers and stakeholders is essential; this is because awareness creates a sense of responsibility among the local community, and thereby helps to sustain the development project in their local environment.

Table 4.32 The interest of farmers in the intervention of the NABU in wetlands

Kebele	Respondent	I Need Support	I Do Not Need Support	I Do Not Know
Kidest hana	69	39 (56.5%)	6 (8.7%)	24 (34.8%)
Shina	81	44 (54.3%)	11 (13.6%)	26 (32.1%)
Shaga	57	30 (52.6%)	7 (12.3%)	20 (35.1%)
Wagetera	91	54 (59.3)	15 (16.5%)	22 (24.2%)
Nabega	87	53 (60.9%)	13 (14.9%)	21 (24.1%)
Total	385	220 (57.1%)	52 (13.5%)	113(9.4%)

4.1.4.7. Wetland Reduction Detection

Increased rice crop production is negatively correlated with cattle population (Fig. 4.22). This is because the price of rice encouraged the farmers to incorporate wetlands into their farmland to produce more rice. Therefore, rice production has not only intensified, there has also been an extensification of rice crop area in the studied wetlands.

In the past, the border of Lake Tana and wetlands were covered by vegetation, such as reeds, *Butia capitata (palm tree*) long grasses, and papyrus. Currently, the vegetation has been removed around the shoreline of the Lake and the wetlands because of flood recession farming and for dry season small-scale irrigation (Fig. 4.29A&B).

Hence, the effects of recession farming on wetland and lake resources have been demonstrated with changes in the color of water, increased siltation and turbidity of the water, and decreased flow quality. Recession farming has had a detrimental effect on the fauna, flora, and hydrology of the study site. New lands were developed at the land/swamp interface as a result of the recession and the draining of wetlands, resulting in major destruction of the wetland environment.

(**A**) (**B**)

Fig. 4.29 Flood recession farming (A) and small-scale irrigation (B) near Lake Tana and wetlands

4.1.5. Cross-sectoral Institutional Linkages needed for ensuring the Sustainability of Biosphere reserves in Fogera Wetlands

In this section, the researcher tried to explore the activities implemented and the interaction of sectors in the wetlands of the study area. It is summarized in the following forms from different experts' views of the wetland and their actions. This section indicated the activities worked and whether the sectors have cross-sectoral institutional linkages for sustainable wetlands of the area or not.

4.1.5.1. Agriculture sector

The existing and previous resources of Fogera Wetlands explained that the wetlands in the past had different resources like papyrus, fish, and wetland resources such as small and big grasses, grazing land, bush trees, and Fogera indigenous livestock rearing places. In the past, most of the farmer's livelihoods depended on the rearing of Fogera indigenous livestock, fish harvest, and small farm activities, but currently in this study area, the wetland resources are very limited, and the activities of the farmers have shifted to rice production, vegetation, and other crops.

Rice production was started in the 1970s with a small number of farmers and expanded to the whole floodplain of the Fogera area. This production has an impact on the Fogera indigenous livestock production, grazing, and wetlands of the area. The impact implies a reduction of wetland resources, such as the disappearance of papyrus, reed, fish, hippopotamus, and others in the floodplain and the border of Lake Tan. There are no regulations or rules to protect the wetlands; rather, they encourage farmers to expand their farms to the wetlands and Lake Tana in the form of recession farms because the sector is giving more attention to rice production than the wetlands.

Regarding artificial input use, they explain that it is very important for the increase of rice yield, but it has impacts on water and soil pollution in the area. The monitoring efforts have not been implemented by government and non-government organizations as well. There are no formal or informal institutions that can ensure the sustainability of the Fogera wetlands.

4.1.5.2. Environmental Protection and Land Administration Authority

This sector has a high responsibility to sustain the wetlands and Lakes found in the Amhara region. Even though the sector has such responsibilities, it doesn't perform as expected. Whatever the sector tries to do, certain important things are that it has a strategy for sustainable land administration and land use practices in the area. This is land registration, which may be a good opportunity for the community and may be important for their land insecurity.

The agriculture and land administration offices do not work together in collaboration to sustain the wetlands rather than focusing on rice production. The expert explained that there is a land use change observed in the wetlands and grazing lands, which changes most of the wetland and grazing lands into rice farming areas. Currently, when the area is compared with the previous time (before the rice introduction), it is observed that there is a greater reduction of wetlands and grazing lands but a tremendous increase in rice farming.

4.1.5.3. Water sector

Regarding the water development in the Fogera wetlands (floodplain), water extraction from underground is now practiced in the floodplain, and there is also irrigation practice using the Ribb and Gumara rivers bordering the study area. The water condition of the wetlands area is reduced from time to time, which is an indication of water pollution. Still, there are no mechanisms to control water extraction and pollution in the wetlands of the study area. There is a change in the situation of the water in the wetlands due to the introduction of rice crops in the floodplain, which changes the attitudes of the farmers towards rice production without considering the problems of the environment in the study area. The expert explains that there is also artificial input application and sand mining in the area, which aggravates water pollution in the study area.

Therefore, it is alarming for the sustainability of the wetlands of the study area in particular and Lake Tana in general, which need a win-win strategy for livestock production and the sustainability of the wetlands and Lake Tana. Based on their comments, it needs forage development strategies for sustaining the indigenous Fogera livestock breed, rice production, and wetland loss reduction, and then, if possible, avoid environmental trade-offs.

4.1.4.4. NABU office

The role of BR in wetland management in the Fogera wetlands is eye-opening when considering the problems of the wetlands and Lake Tana. The BR focused on the sustainability of the wetlands and Lake Tana. This is a good opportunity to sustain the wetlands and Lake Tana around the Fogera area. The organization NABU has a very good opinion about saving the wetlands and Lake Tana. Their idea is that the wetlands and floodplain can be used for the production of indigenous cattle populations, rice production, and other wetland resources through sustainable use and conservation of the resources. This organization can support the community by creating awareness regarding the importance of the sustainability of the environment and encouraging them to practice indigenous knowledge and pay attention to the sustainability of production and the environment.

4.1.4.5. Wetland Association

The Wetland Association has made some efforts to solve the problems of the wetland area by treating the upland areas through seedling plantations for the conservation or reduction of runoff to the floodplain. This wetland association does not have any guiding policies for the wetlands in the Fogera area.

4.1.4.6. Tourism sector

Tourism office experts explain that the activities practiced in the Fogera area are almost nonexistent. This sector needs to work together with the coordinator of the Biosphere Reserve around Lake Tana. In the biosphere reserve area, especially on the island of Lake Tana, they tried to organize the youth to generate their income from tourists coming to visit the monarchy. When considering the advantages and disadvantages of tourism activities, most of the activities have positive outcomes in this study area because they generate income for the community around the tourist site in particular and for the country in general.

The negative impact may be pressure on wildlife, if any. The expert mentioned that the Fogera area is a potential site for tourist attraction, and organizing the youth and others could be good to generate income for the community because there are different birds, hippocampus, and the view of the wetlands, Lake Tana, and the Ribb and Gumara rivers in the floodplain of Fogera.

4.2. DISCUSSION

Not a single respondent felt that the land was public or that anybody outside their kebele could use its natural resources. Overall, 85% of respondents thought wetland ownership was communal, or a CPR available to the kebele. Similarly study by (Ketema, 2013) explained that open access does not imply any kind of ownership (no property rights of anyone) but it may be used or exploited by everybody. So, it may be exposed to the risk and possibility of over-exploitation and degradation

Farmers in the study area tended to have the greatest area sown to teff as well but variability for teff area among farmers within kebeles was high. In line with this, Bayable *et at.,* (2021) reported that Teff (*Eragrostis tef (Zucc.)* is a cereal crop and the major staple food crop grown in Ethiopia. Nearly all farmers grew rice during the rainy season irrespective of kebele (Fig. 4.3). Nowadays, China, India, Indonesia, Bangladesh, Vietnam, Thailand, Burma, Philippines, Japan, and Brazil are the top ten rice-producing countries respectively. In Africa, rice is becoming a staple food and there has been increasing demand in Africa in the past three decades (Mesfin and Zemedu, 2016).

Overall, rice area increased by 2397 ha whereas "water and others" decreased by −502 ha. This is in line with other similar studies in Asia on rice-cropping system changes on floodplains (Guan, 2016; Sakai, 2021). The farmland Fogera floodplain, before the introduction of rice, was 158.75 ha but after the introduction of rice this number flipped to 284.75 Ha or an increase of 126 ha (Fig. 4.10). A study of rice commercialization in the Fogera floodplain revealed similar conditions (Alemu *et al.*, 2018).

This spraying of pesticides kills insects and those insects are eaten by birds (Fig. 4.13). Therefore, the birds could be affected. This is in line with other studies that confirmed the ecosystem functioning effects of pesticide application on rice (Sattler, 2018).

Recession farming is considered as a disadvantage for certain users because respondents linked it to the increasing number of hippopotamuses and birds that damage their crops, and there would be no free fish harvest in the wetlands and the lake (Fig. 4.15). Dejen and Anteneh (2015) mentioned related effects of recession agriculture in the Fogera floodplain. In addition, the effects of recession farming on wetland and lake resources have been demonstrated with changes in the color of water, increased siltation and turbidity of the water, and decreased flow quality. Recession farming has had a detrimental effect on the fauna, flora, and hydrology of the study site. New lands were developed at the land/swamp interface as a result of the recession and the draining of wetlands, resulting in major destruction of the wetland environment. Several studies have found a gradual shift in farming system enterprises from terrestrial to wetland-based development by households close to wetlands (Kipkemboi, 2006).

The increasing trend in rice-cultivated land is supported by the fact that wetlands are characterized by fertile soil and sufficient water, which resulted in more land for rice production (Lakew, 2014). Farmers in the study area tend to grow rice because of its high yield and high market price relative to other food crops (Gebey, 2012). The introduction of rice has changed the production system, especially in the wetlands of the Fogera floodplain, from livestock-dominated to rice-dominated. Mono cropping is the most common cropping pattern recorded in the studied wetland areas, in line with the results of Tilahun *et al.,* (2013). This affects the biodiversity in the Fogera floodplain as studies indicated (Abebe *et al.*, 2021).

Before the introduction of rice, manure was used instead of chemical fertilizer to grow maize *(Zea mays L.)* and green pepper *(Capsicum spp.)*, being that the soil was extremely fertile (Gebresllassie, 2014). According to FGD participants, soil fertility depletion and the addition of sand and other unfertile soil particles from upland erosion to the study area's wetland decreased soil fertility and the amount of water in the wetland. This resulted in the use of agricultural inputs (chemical fertilizer, improved crop, insecticide, and herbicide) (Gebresllassie, 2014). These have contributed to the biodiversity loss of the Fogera floodplain wetlands, as previous studies confirmed (Anteneh, 2012). For example, rice cultivation allowed for a landscape rich in diversity, particularly in macro-invertebrates, fish, and waterfowl until the early twentieth century in rice-producing Asian countries, but the intensification of agricultural practices has changed their ecological character significantly (Shimoda, 2007).

After the start of chemical input applications, according to respondents, there is recognized water contamination, extinction of wetland vegetation such as papyrus, and a decrease in the number of birds, bee colonies, fish, and other animals such as macro-invertebrates, reptiles, and amphibians in the Fogera floodplain wetlands. This is in line with Garcia (2020) that rice intensification results in an expansion of land under production; it will generally have negative impacts on the environment owing to habitat loss. This had a significant negative impact on the attractiveness of the local tourism-based economy (Wondie, 2010). Earlier studies revealed that traditional rice systems were sufficiently multifaceted ecosystems that did not involve the use of chemical fertilizers but had optimum production for longer periods.

Flows in the dry season in March and April increased in time likely due to the flow releases from the upstream Ribb dam during construction time, and May to September (rainy season) decreased likely due to that the dam holds water. This is contrary to the Gumara River, with no dam, which also floods the Fogera floodplain (Abebe, 2020).

Seasonal and annual variations in the hydrological functions of the study wetlands were observed. In line with this, floodplain wetland communities have also recognized the decline in water level in the wetlands, where there is a loss of fish, depletion of papyrus and other wetland grass species, and disappearance of the hippopotamus population as well as migratory birds. In aquatic ecosystems, hydrological regimes create biotic diversity, and hydrological variation is recognized as a primary driving force (Wondie, 2018). When humans alter the flow regime, the normal cycle of hydrologic variation and ecosystem dynamics is disturbed (Anteneh *et al.*, 2012).

Aside from better land-use practices, livestock overgrazes and macrophyte overharvesting in the Fogera floodplain play a synergistic role in disrupting the area’s hydrological cycle and microclimate regulation. As wetland macrophyte vegetation disintegrates due to over-exploitation and loss of wetland vegetation, pollutants, and nutrients are transported directly into the lake (Wondie, 2018). The euphotic zone in littoral area lakes gets shallow due to increased turbidity caused by the destruction of the buffer zone vegetation by cultivation, suggesting a drastic drop in water quality.

Wetland areas were greatly reduced in favor of rice from time to time due to rice intensification. Studies by Wondie (2018) and Mohammed and Mengist (2019) mentioned similar conditions which indicated that the wetland surface area has been greatly reduced due to intensive agriculture, free grazing, and population density.

It is also crucial to understand how wetland habitats are used for rice production to preserve their long-term viability. The study investigated the impact of rice prices on the expansion of rice production and traditional wetland management in the Fogera wetlands, on the eastern shore of Lake Tana, using a combination of approaches, including key informant interviews, (FGD) of sampled farmers, records of hydrological alterations in the floodplain wetlands, and spatial analysis of land use changes. The areas of both permanent and seasonal wetlands have declined, while agricultural land has expanded, according to these findings. Because rice has a higher price than other crops, it is encouraged to expand agricultural land at the expense of wetlands and grazing grounds. This issue is consistent with the findings of Gebremedhin *et al.*, (2012), who found that rising rice prices increased the extension of rice production, encouraging farmers to expand rice farming into wetlands.

All of the foregoing difficulties corroborate the findings of this paper, showing that the natural resources of the wetlands of Fogera were lost in recent years as a result of the increase in rice production in the Fogera wetlands. Hence, the functions and services of wetland resources have been diminished as rice expansion has taken place at the expense of wetlands. Concomitantly, there were also hydrological changes in the wetland floodplain areas, which caused normal hydrologic functions and services to be disrupted. For instance, a study of the connected Gumara River indicated that the migratory Labeobarbus fishes, which inhabit the Fogera floodplain, are declining as a result of the hydrological alteration that has been ongoing for the last 20 years (Abebe *et al.*, 2021).

Many rivers have been drained to raise crops; additional effects include water diversion via irrigation canals and excessive water extraction for intensive agriculture. Wetland water can be contaminated by fertilizers, pesticides, and other agrochemicals. As a result of humans attempting to boost agricultural output, many wetlands have been significantly and irreversibly altered (McCartney, 2014).

Currently, the livestock population decreased because of the intensive practice of rice agriculture. Since the 1970s, rice production practices have been introduced in the wetland areas of Fogera. According to the Fogera Woreda Agriculture Office, participant farmers in rice production have been increased, and on the contrary, the number of livestock decreased over time. IBC (2004), and Gebeyehu *et al.*, (2004), the pure Fogera cattle population dropped in addition farmers compete to obtain land as the floodwaters retreat for the recession farming instead of left it for grazing (Tadesse and Solomon, 2014). Therefore, due to the rice farming approach, the number of grazing land is reducing over time and it affects Fogera indigenous cattle.

In terms of household income, the expansion of rice production was largely positive but the livestock number and their production as well as their movement were reduced (Tadesse and Solomon, 2014). Fogera has a high potential for dairy production, but according to Woreda agricultural experts and Belete (2006), due to the feed shortage, farmers from highland kebeles move indiscriminate breeds to the plains during the dry season, which has resulted in the reduction of the better yielding Fogera breed in the plains.

Insufficient land, problems of labor, lack of inputs such as forage seeds, and lack of information were among the reasons given by respondents for not growing their own fodder. The area of the communal grazing land and rice crop residues are the main and the only feed sources available for the farmer's livestock feed as indicated. Generally, there is an insufficient amount of grazing land, and as a result, the productivity is also low due to feed. The main reason, as mentioned above, is the introduction of rice production which influences animal rearing. Belete (2006) approved not only the reduction of their number but also productivity. In the area, the conversion of grazing lands into crop production especially rice, in this case, seems the main reason for the scarcity of feed resources. This was also approved by land use/land cover detection in the GIS environment and the amount of grazing land was changed over time.

Agriculture land was pushed into formerly grazing and wetland areas. It has also been observed in the study site that the built-up areas were mostly surrounded by agricultural areas. It means the area near the population has been cleared and shifted to crop production to fulfill the necessities of life. The introduction of rice farming caused the expansion of agricultural land at the expense of other land-use types in the area (Mesfin *et al.,* 2016). In the Woreda, rice is one of the food crops produced by the majority of the farmers in a study conducted by Gebremedhin and Hoekstra (2007).

The area covered by wetland and grazing class has also witnessed a decrease from 1973 to 2021. The land use/land cover changes observed in all other classes affected the wetlands and grazing class during four decades. According to Taddese and Solomon (2014), the overall land use/land cover change analysis of the Landsat image of the years 1986 and 2013 in the Gumara and Ribb watershed showed that grazing land has declined drastically and cultivated land hasrapidly increased. Moreover, the grassland use type was changed into settlement and eucalyptus woodland. This increasing trend of LULC in the study area reinforces that economic forces are commonly a major stimulus on anthropogenic change of land (Wang *et al.*, 2008).

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study endeavored to characterize socioeconomic attributes of farm households and household-head perceptions towards factors related to sustainable wetland management with a view towards finding better paths towards reversing land and water degradation. Kebeles differed significantly for household-head age and education, but overall education level was low. These are smallholder farms, with mean farm area of less than one ha, and mean farm area varying among kebeles. Whatever it is practically all farmers grew rice. Irrespective of kebele, age, level of education, or gender, not a single respondent had any familiarity with any organization, whether governmental or non-governmental, working on issues of sustainable wetland management in floodplain of Fogera wetland.

The study also revealed that local population hold significantly more positive attitudes towards wetlands and wetlands conservation. This includes their determination to control activities causing wetland destruction or degradation, willingness to support Nature and Biodiversity Conservation Union office efforts for wetlands conservation. These positive attitudes of communities towards wetlands and wetlands conservation offers some hope for sustainable utilization of wetlands. Despite the positive attitudes held by the majority of respondents, there is no institutional or governmental support for raising wetlands conservation awareness and more effective wetlands use by residents. Thus, there is no proactive approach by government to reduce wetlands degradation and help conserve the remaining areas of wetlands.

With regard to temporal and spatial changes in cropping patterns, use of inputs and hydrological alteration on Fogera wetlands, there is spatial increase in rice-cropping and temporal changes in crop production in the Fogera floodplain. The introduction and expansion of rice farming in the study area were at the expense of draining the wetlands and grazing land losses. In addition, the agricultural input applications on rice fields have also increased. Dry monthly flows have an increasing trend in the beginning months of the year, and later months showed a decreasing trend, but rainy season months showed an overall decrease.

The diversity of herbaceous vegetation in the three Kebeles of the Fogera floodplain was found to be lower than the overall average index. Changes in wetland hydrology can affect soil chemistry as well as the plant and animal population in wetlands. Altering the natural amount of water entering a wetland or the cycle of saturation and inundation will cause the deterioration of biodiversity and loss of ecosystem services. The application of inputs caused water pollution and soil degradation. These have an effect on wetlands that play an important role in water purification, nutrient preservation, flood prevention, and erosion control. Generally, intensification of farming practices has an impact on the biodiversity of fauna and flora of the floodplain area Fogera wetlands.

With regard to the impacts of rice cultivation on an indigenous Fogera cattle at the Eastern shore of Lake Tana, Fegera wetlands, the livestock feed sources are becoming declining due to the excessive conversion of grazing lands into cultivated land and built areas. The overall livestock productivity is a function of high human and animal population which in turn results in a shortage of pasture land. Moreover, most of the communal grazing/browsing lands are degraded providing only limited feed. In general, feed shortage and poor performance of local breed (because of unwanted breeding) affect the productivity of Foger livestock breed.

Based on the results obtained by the employment of GIS and remote sensing applications to achieve the specific research objectives, it is concluded that the land use/land cover practices in the study area have altered significantly in 48 years. The LULC shift in the study kebeles was evident by the decline in the area of grazing land, bush, and shrubland and augmentation of the area covered by classes of agriculture and built-up areas. The haphazard expansion of built-up areas and agriculture area in the study area was mainly due to the lack of proper management and land-use planning since no Environmental Impact Assessment (EIA) report is generated prior to land development in the study area. The major impact of this expansion was subjected on grazing, bush and shrubland, and wetland class to forage resource reduction, deforestation, and water depletion, respectively.

With regard to the environmental tradeoffs of rice intensification on traditional wetland management in the Fogera wetlands, the wetlands in the Fogera floodplain are the hub for aquatic biodiversity that contribute significantly to the local community’s income, food, and jobs. Nowadays, the majority of the community relies on arable land for agriculture, particularly rice production, and relatively small-scale fisheries in the wetlands provide food security and jobs for the area's rural inhabitants. Because of the strong demand for, and limited quantity of, rice on the market, thus making rice more profitable, farmers are attempting to expand rice production in wetlands, having switched from their previous conventional agricultural practices to rice production systems. This current rice agricultural production system is incompatible with wetland resources or wetland TEK preservation.

Therefore, traditional wetland management practices were influenced by the rice market, as the increase in the prices of rice grain led to departures from traditional practices. This leads to the loss of wetland resources that was available before the start of rice intensification like local boats made from the stem of papyrus, use of papyrus leaves during a ceremony, "Senele" (*Butia capitata*) for a (mat, hut and (mackintosh or raincoat) making, roof thatching, Papyrus for home campus fence, Reeds (for rope) and brooms *made from Butia capitata*. All there are the loss of the resources and the indigenous knowledge which of the environmental trade-offs.

With regard to the institutional linkage mechanisms that facilitate rice intensification by offsetting environmental trade-offs and ensure the long-term sustainability of important biosphere reserves in Fogera wetlands, the institutions in the wetlands were tried to implement their activities without integration. In the Fogera Wetland, resources like wetlands are shared as public assets, and no one organization is visibly in charge of administering the resources.

The Institutions and the relationship and relative importance of formal and informal institutions, Actor networks with emphasis on the role and interactions of state and non-state actors, Multi-level interactions across administrative boundaries and vertical integration were required to work together. Even though it is necessary for institutions to work together to address wetland issues in the Fogera wetland, there is currently minimal interaction among organizations with related goals. These organizations don't communicate adequately when it comes to safeguarding wetland resources. There is no official framework for cooperation and knowledge sharing about wetland management.

In general conclusions of this study agree with those of prior studies on two major points. The first is agricultural development with the intensification of rice production in wetlands, and the second is the threat that wetlands face when their resources are depleted. Further research is needed to determine the value of lost wetland area versus increased overall revenue for farmers, as well as the win–win scenario for future development, while considering the area's wetland resource sustainability.

5.2. RECOMMENDATION

- The Fogera floodplain needs to be regulated based on a wetland management plan and the already established proclamations for biodiversity conservation areas in this region.
- Encourage to preservation of indigenous knowledge and practices so that wetland systems and rice cultivation can co-exist in a win-win arrangement
- Use of agricultural inputs must be regulated towards efficient use of inputs as a common goal in sustainable intensification practices.
- Moving towards organic rice cultivation and developing their organic brand might help framers to get better prices but also minimize pollution of wetlands
- Environmentally friendly, non-intensive production processes, and the marketing of regional products, should be encouraged even more to sustain wetlands.
- Organic farming works in harmony with nature rather than against it. This involves using techniques to achieve good crop yields without harming the natural environment or the people who live and work in it. Searching for organic rice crop brand certificates for Fogera floodplain rice-producing farmers could be better.
- Raising public awareness, developing independent wetlands policies, enhancing organization-to-organization cooperation, creating buffer zones, and ongoing monitoring are key policy and institutional issues that need to be practiced to save Fogera wetlands and Lake Tana
- Complete draining of wetlands limits the entire range of advantages they produce and includes a trade-off of benefits, with some gains and some losses
- Sustainable intensification of rice farming requires community-driven strategies, local development and cross-sectoral institutional linkages through encouraging indigenous practices and knowledge to avoid or reduce environmental trade-offs.
- The Lake Tana Biosphere Reserve administration should be better integrated and used to promote local eco-tourism to preserve traditional knowledge and practices involving wetland resources.

- Fogera indigenous cattle are the best in their milk and meat production, it needs to be restored.
- In general, feed shortage and poor performance of local breeds (because of unwanted breeding) affect the productivity of livestock. So, the concerned body should take measures that could enhance improved feeding management techniques such as rotational grazing for extended pasture lands, forage development, fodder conservation, feeding fresh forage using the cut-and-carry system, and regulating the intake by different categories of stock to fill the gaps livestock feed.
- Establish a stronger Traditional Ecological Knowledge framework and policy; the research community should conduct more studies at the national and regional levels. As a result, policymakers and stakeholders must collaborate on wetlands management, vis-à-vis, rice production intensification.
- Hence, proper management of Fogera wetland resources is required because, without proper management, these valuable resources like grazing, wetlands, fish, birds, papyrus, reds and water resources will soon be lost or will no longer be able to play their required role in the socioeconomic development of the area.
- To sustain wetlands with the coexistence of rice production, concerned bodies have to join the programs that help protect and restore wetlands, report illegal activities and use living shoreline techniques to stabilize the soil, avoid artificial input use, stop the expansion of rice activities on wetlands and grazing lands, and give more attention to innovative traditional farming systems.

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APPENDIX: I

Sample farm households' questionnaires schedule (most of them are adapted from Astewel 2010)

Instructions:

Make a brief introduction to each farmer before starting the interview; greet them in the local way; know each other and ask his/her name; tell them the purpose and objective of your study;

After getting the informed consent of respondents, please, ask each question so clearly and patiently until the farmer understands;

Please, fill up the interview schedule according to the farmer's reply (do not put your own opinion);

Please, do not try to use technical terms while discussing with farmers and do not forget to use/record the **local unit**;

During the process;

1: **Write** the answer of the respondent on the space provided,

2: **Ask** & **write** details where required,

3: **Encircle** or **tick** the chosen answer;

Prove that all questions are asked and the interview schedule format is properly completed; and

At the end, leave farmers with words of thanks

General Information

Name of Respondent: ____________________________________

District: ____

Peasant Association (PA):_________________________________

Name of Village: _______________________________________

Date of interview: ______________________________________

Name of enumerator: __________________

Signature:__________________________

Questionnaire code: ______________________________________

PART ONE: **<u>Socio-Economic characteristics of the respondents</u>**

No.	Name of HH Members (*use the first name only and start with the HHH*)	Relation with the HHH *(use the code specified below)*	Sex Male=1 Female= 2	Age --years	Marital Status Single =1 Married =2 Divorced =3 Widowed =4	Education Level Illiterate, no schooling =1 Adult Education =2 Grade 1-4 =3 Grade 5-8 =.4 Grade 9-10 =5 Preparatory(11&12) =6 Higher education = 7 Other(Religion) = 8	Occupation Farming =1 Off-farm =2 1&2 =3	Languages 1= Am 2 = Or 3 =Ti 4 =Aw	How long did you live in this village
1									
2									
3									
4									
5									
6									
7									

HH- Household; HHH- Household Head

NB: please specify those nonfarm and off-farm activities that sample HH engaged in it.

Code for Question about relation with the HHH

Head………………... …….. 01	Uncle/Aunt …………………………………08
Wife/husband……………… 02	Cousin ….………………………………......... 09
Son/daughter……………........ 03	Grand Parent..10
Father/mother……………… 04	Children from another family………….........11
Sister/brother………….........05	other non-Relative……………….……….. 12
Stepson/stepdaughter………. 06	other relative……………………………… 13
Stepfather/stepmother……… 07	Renter ………………………….…………..14

Questionnaires

1. Do you have your own agricultural land? Yes = 1 No = 2
2. How many plots of land do you have? ____________
3. What was/is the size of your farmland?
   a. Before the introduction of rice in Timad_________
   b. After the introduction of rice in Timad __________
4. If your answer for No 3 is increased, how do you get the land? ________
5. Is your farmland sufficient to produce food for your families?

   Yes = 1 no = 2
6. Which types of crop do you produce?

   a. ________ b. __________ c. _________ d. _________ e._________
7. Do you face a disaster on your crop due to flood coming from upland agricultural areas?

   yes = 1 No = 2
8. If your answer for No 7 is yes, which year? ______________
9. please fill the table below with the area cultivated in and the amount of crop yield produced for the last nearest two cropping seasons

No	Crop type	2014					2015			
		Cultivated land in Timad	Crop variety used	Production in quintal			Production in quintal			
				Total production	Grain used for food	Grain used for marketing	Total production	Crop variety used	Grain used for food	Grain used for marketing
1	Rice									
2	Teff									
3	Vitch									
4	Check pea									
5	Potato									
6	Tomato									
7	Red onion									
8	white onion									
9										

10. If there is an increase in production, what are the causes?

    Fertilizers = 1 manure = 2 improved seed = 3 fallowing = 4 crop rotation = 5

    Using insecticides = 6 using herbicides = 7 others (specify____ = 8

11. What is the cause for the decreasing in crop yield if there is in the above crop? ________
12. What type of cropping pattern do you practice?

    Mono crop = 1 crop rotation = 2 intercropping = 3 others (specify) _____ = 4
13. What types of agricultural inputs do you use to increase crop yields?

    Fertilizers = 1 improved seeds = 2 local seeds = 3 manure = 4

    Pesticides = 5 herbicides = 6 others (specify) _ = 7
14. When do you start using artificial inputs? (mention the artificial inputs along with year _____)

No	Artificial input used	Starting year	No	Artificial input used	Starting year
1	DAP or Urea		4	Herbicides	
2	Natural (compost)		5		
3	Pesticides		6		

15. What benefits did you recognize from using artificial inputs?

    Increase production of crops yield = 1 decreasing of crop yields = 2 No change = 3
16. What negative impacts do you recognize from using artificial inputs?

    Water pollution = 1 Death of Birds = 2 Killing of bees = 3 killing of fish = 4

    Killing of other insects = 5 others (specify) _____ = 6
17. Do you produce crops in the form of recession farming? Yes = 1 No = 2
18. If your answer is yes for No 17, what problems do you observe on wetland resources?

    No change = 1 increase on wetland resources = 2 Decrease on wetland resources = 3
19. What changes have you observed in wetlands and water resource on your farmland? Explain ____
20. Which wetland and Lake Resources reduced from time to time? (Rank them)

    Papyrus ____ Fish _____Sand ____Birds _____Grass _____amount of water _____

    hippopotamus ____ others (specify) ___
21. What problems do you face due to the reduction of wetland and Lake resources?(rank them) Flooding ___siltation __widening of river ways ___ turbidity of water ___others (specify) ___
22. Do you want to conserve the wetland of Fogera?

    I strongly want =1 I want = 2 I do not want = 3 I strongly do not want = 4

23. If your answer for No 22 is 3 or 4, explain your reason.___________________
24. What are the benefits from the conservation of wetland of Fogera? Getting _____

    1 papyrus 2 fish 3 sand 4 birds 5 grass 6 Pure water 7 moderate climate 8 reduction of flood 9 high amount of water 10 others mention ---
25. What are the demerits of conservation of wetlands of Fogera? ________________

    1. No use as you wants 2. Increasing of number of hippopotamus and birds damage crops 3. No free grazing 4. Others mention --------------
26. What was the practice in the land when you were young? Explain_________________
27. Do you observe a significant land use change on wetland areas + the land reform of 1989 E.C.? Yes = 1 No = 2
28. If your answer is yes for No 27, what are the main reasons for the change?

    Scarcity of agricultural land = 1 scarcity of grazing land = 2 population growth = 3 Due to introduction of rice = 4 unemployment = 5 others (specify) __________
29. What are the wetland resources? _____________
30. Do the land use changes reduce (affect) the wetland resources? Yes = 1 No = 2
31. If your answer is yes for Nº 30, what are they? ______________________
32. What are the negative impacts of wetland resource reduction on Lake Tana?

    Siltation = 1 seasonal over flow of water = 2 reduction of fish resources = 3
    Reduction of birds around the Lake = 4 reduction of papyrus = 5
    Lake water pollution = 6 others (specify) ___________
33. What is the current condition of wetland resources?

    Increase = 1 decrease = 2 no change = 3
34. If you answer is 2 for No 33, what is the reason? Mention them ____________
35. What is your main source of income? You can choose more than one.

    Producing rice = 1 producing other crops = 2 animal rearing = 3 fishing = 4 sand mining = 5 selling artifacts = 6 Petty trade = 7 selling of wetland resources (like papyrus) = 8 Vegetable production = 9
36. How much do you earn from agriculture (your income)? Monthly____ Annually ____
37. How much income do you gain annually from rice production only? _____ in Birr
38. How much do you earn from off-farm ____in Birr and other remittance ____in Birr
39. Is there any job opportunities created due to rice production? Yes = 1 No = 2

40. If your answer is yes for No 39, what are the types of employments?
    Daily labor during sowing = 1 Daily labor during weeding = 2 Daily labor during harvesting = 3 Daily labor during threshing = 4 transportation for rice grain = 5 opportunities for rice polishers = 6 others (specify) _____ = 7
41. How do you get additional labor sources for rice production?
    Household members = 1 hiring of daily labor = 2 “Wonfel” group of neighborhood = 3 relatives and friends = 4 others (specify) _______ = 5
42. What are the costs of production for the 2014 in Birr? 1 Daily labor___2 Land rent (if any)___ 3 Fertilizer____ 4 seed____5 pesticide ___6 herbicide __ 7 Transportation __
43. What are uses of wetland for you and your households?(you can choose more than one)
    Farming = 1 selling papyrus products = 2 Drinking water = 3
    Grazing = 4 fishing = 5
44. Do you have children to school? Yes = 1 No = 2
45. If your answer is no for No 44, why? __________
46. What kinds of road access do you have?
    All weather road = 1 dry weather road = 2 no road = 3
47. What kind of transportation system do you use for travel?
    Vehicles = 1 back of animals = 2 on-foot = 3 others (specify)____ = 4
48. Do you use rivers for irrigation? Yes = 1 No = 2
49. If your answer is yes for question 48, which river do you use?
    Rib = 1 Gumara = 2 other river (specify) ___ = 3
50. Do you extract ground water for irrigation? Yes = 1 No = 2
51. If you answer is yes for No 50, from where do you extract?
    From my village compound = 1 from my farmland = 2
    From communal wetland = 3 from the Lake = 4
52. Do you agree on the effects of rice production with artificial inputs on wetland resources?

Strongly agree = 1 agree = 2 neither agree nor disagree = 3 disagree = 4 strongly disagree = 5

53. How do you evaluate wetland resources compared to the introduction of rice?
    Highly reduced = 1 reduced = 2 no change = 3 increased =4 highly increased =5
54. If your answer is 1 for No 54, what wetland resources are highly reduced?
    Fish = 1 sand = 2 amount of water in the wetland = 3

Papyrus = 4 birds around wetland = 5

55. Do you agree on that rice production changes the life of the community?

    Strongly agree = 1 agree = 2 neither agree nor disagree = 3

    Disagree = 4 strongly disagree = 5 don't know = 6

56. Would you support or oppose recession farming in your community?

    Strongly support = 1 support = 2 neither support nor oppose = 3

    Oppose = 4 strongly oppose = 5

57. How effective would be establishing system for conserving and sustainable utilization of wetland resources in your community?

    Very effective = 1 effective = 2 not effective = 3 not very effective = 4 don't know = 5

58. Have you ever used agricultural inputs (fertilizer, chemicals, etc.) for the production of rice? Yes = 1 No = 2

59. If your answer is no for No 58, what was the main reason behind? ___________

60. If your answer is yes for No 59, which type and from which source do you get such agricultural inputs for rice production? Put in the table below.

No	Input used		Amount	Price in Birr/quintal	Sources of input
1	Improved seed (kg)				
2	Local seed (kg)				
3	Fertilizer in quintal	Urea			
4		DAP			
5	Pesticides (lit or kg)				
6	Herbicides (lit or kg)				

61. Do you use organic fertilizer or compost for rice production? Yes = 1 No = 2

62. If your answer is yes for No 61, list the organic fertilizer you used___________

63. If your answer is no for No. 61, explain the reasons__________________

64. Livestock holding of the household

Species of Livestock	No	Species of Livestock	No	Species of Livestock	No
Ox		Heifer		Sheep	
Cow		Mules		Chicken	
Calf		Donkey		Bee Hives	
Bull		Goats		Others (specify) -----	

65. Livestock breed assessment **(NB you can choose more than one)**

<table>
<tr><th rowspan="2">No</th><th rowspan="2">Breed type</th><th rowspan="2">Number</th><th rowspan="2">Purpose</th><th colspan="4">No of livestock within mentioned year</th><th rowspan="2">Main cause of the change</th><th>Main cause of the change</th></tr>
<tr><th>20yrs ago</th><th>10yrs ago</th><th>5yrs ago</th><th>Present</th><td rowspan="6">1. Rice production
2. Less productivity of livestock
3. market problem
4. Problem of fodder
5. Diseases of livestock
6. problem of house for livestock
7. problem livestock breed
8. lack of capital
9. less price of livestock
10. water shortage for livestock
11. introduction of new breeds
12. lack of grazing land
13. High productivity of 1livestock
14 High price
15. others (specify) __</td></tr>
<tr><td>1</td><td>Fogera</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>other Local</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Exotic</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Cross</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Mixed</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

66. How much annual income do you gain from livestock? _________________ in Birr

67. How do you get fodder? Communal land of wetland = 1 buying fodders from others = 2 crop residue = 3 rice residue = 4 others (specify) __ = 5

68. Does rice production contribute for reducing the type and number of local breeds of Fogera livestock? Yes = 1 No = 2

69. What kinds of grazing system do you use for your livestock? Cut and carry system = 1 Rotation system = 2 open grazing system = 3 others (specify) ____ = 4

70. Give your suggestion for sustaining Forgra livestock breed in the wetlands. _______

71. Who is the owner of the Wetland areas?

    Public = 1 Private = 2 Communal (like grazing) = 3

72. Who is responsible for the utilization of wetland resources?

    Community = 1 kebele leader = 2 kebele developing agents = 3

    Cooperatives = 4 small scale association = 5 I do know = 6

73. Which organizations are working on wetlands of Fogera?

Non-Governmental Organization (NGO) ____ = 1

Government organization _____ = 2 I do not know ______ = 3

74. Are there any interventions from NGO's on wetland resources utilization?

Yes =1 No =2

75. If your answer is yes for No 74, what are the interventions? List them _______

76. Are there any interventions from government on wetland resources utilization?

Yes = 1 No = 2

77. If your answer is yes for No 76, what are the interventions? List them _______

78. What are the different ways by which you support for the sustainable utilization and conservation of wetland resources?

Exposing the illegal user = 1 participating on meeting regarding wetlands = 2

Participating as one member of local committee about wetland = 3 others (specify) = 4

79. Which type of rice production do you follow?

Traditional (sowing seed with broadcast including artificial fertilizers, pesticides herbicides) = 1

Modern (sowing of seeds with row, using mechanization) = 2

80. Are there any crops out of production because of the introduction of rice?

Yes = 1 No = 2

81. If your answer is yes for No 80, what are the types of crops?

List them______________________

82. Do you expend money to get market information (about rice, other crops, fish, etc)?

Yes =1 (how much in Birr ______) No= 2

83. What are the crops that you decided not to produce because of lack of market information? Mention the crops? _____________

93. Did you sale rice that you produce? Yes = 1 No = 2

94. If your answer is yes for No 93, what is the price in Birr/quintal? _______________

To whom do you sale:

For other farmers for seed/food = 1 for any customer = 2 for brokers = 3

Retailers = 4 Whole sellers = 5

Where do you sale:

From market for retailer and Whole sellers = 1

Selling myself in the market as retailer = 2 others (specify) ___ = 3

95. Why did you prefer to sale your production to the above mentioned consumers? explain_

96. Distance of market center from your home/in _______km _______ time

97. What are means of transportation used for your rice production?

Vehicles = 1 back of animals = 2 manpower = 3 others (specify) __ = 4

98. If you were used vehicles, was it easily accessible? Yes = 1 No = 2

99. If you were not used vehicles, why? __________

100. From the following which market problem do you face:

Lack of market information = 1

Poor linkage with other value chain actors (retailers, traders, consumers, etc) = 2

Low consumer demand = 3

Non-availability of market/limited access to market = 4

Low quality product that meet consumer demand = 5

Absence of rice polisher = 6

Market distance = 7

Absence/ limited access to transportation = 8 others (specify) ___ = 9

101. How did you solve the problems that you select from question 100? ___________.

102. Which one of the following market motivation forced you to produce rice?

High consumer demand for consumption of rice = 1

High demand for rice seed from farmers in nearby areas = 2

High market price of rice = 3

Others (specify) _______= 4

103. What are the influences of rice market on traditional practices/knowledge like selling of papyrus, selling of fish, dairy farm of Fogera breed etc)?

Preserves traditional practices/knowledge = 1 it promotes the traditional practices/knowledge = 2 it hinders the traditional practices/knowledge = 3 it illuminates the traditional practices/knowledge = 4 No change = 6 others (specify)- =7

104. Do you think that there is enough supply of rice for market? Yes = 1 No = 2

105. Do you think that there is high demand of rice market? Yes = 1 No = 2

106. What is your suggestion to balance the rice market system? _________________

107. Are there any traditionally produced goods from wetland resources in Fogera wetland?

Yes = 1 No = 2

108. If your answer is yes for question 107, what are they?

	Types of traditionally produced goods	Price (Birr)/piece

109. Do you agree on the effects of rice market on wetland resource?

Strongly agree = 1 agree = 2 neither agree nor disagree = 3

Disagree = 4 strongly disagree = 5 don't know = 6

110. Do you support the effort of NABU office to sustain the biospheres in the wetlands of Fogera? I need to support = 1 I don't need to support = 2 I don't know = 3

Interview

<u>For officials of Agriculture and environmental protection and land Administration</u>

1. Explain the existing and past condition of wetland resources of the Kebeles within the BR?
2. Explain how the rice has been introduced and its influence on the wetlands of Fogera Woreda?
3. Is there any law and regulation on the management of wetland resources in the Fogera Woreda? If your answer for question 2 is no, why?
4. Is there any government enforcement on the application of artificial input for the rice production in the Fogera wetland? Why?
5. What is your recognition about the impacts of artificial input use on the wetland resources of Fogera Woreda?
6. What looks like the monitoring efforts of the government to sustain Fogera wetlands?
7. Are there NGOs that are working in relation to wetland resources management in the Fogera Woreda?
8. How do you see the effort of the NGOs on the wetland management?
9. List the informal institution and the NGOs that work in relation to wetland management?
10. What is role of Agriculture and land administration sector on the sustainability of Fogera wetlands?

11. How do you recognize the land use change in the Fogera wetland?
12. What are the causes for the land use change in the wetlands?
13. How do you see the Fogera livestock breed after the introduction of rice in the Fogera wetlands?
14. How do you see the availability of fodder to sustain Fogera livestock breed?
15. What strategies do you have to sustain the Fogera livestock breed?
16. What strategies do you have in relation to forage development to sustain Fogera livestock?
17. Which type of systems do you suggest for the use and managements of common resources of the Fogera wetland?
18. What do you suggest for developing systems for the linkage, integration and coordination of concerned sectors for application of sustainable managements systems for Fogera wetland?

Water Sector

1. Is there any water development in the Fogera wetland?
2. How do you observe water condition of the Fogera wetland?
3. How do you see the controlling mechanism of the ground water extraction in the Fogera wetland
4. Is there any change in the amount of water in the Fogera wetland after the introduction of rice in the Fogera floodplain?
5. What do you suggest about water pollution due you to artificial input use for the production of rice?
6. How do you relate sand mining and water pollution in the Fogera wetland?
7. How do you see the effect of the dam on Fogera wetlands?
8. What are the positive and negative aspects of irrigation on Fogera wetlands?
9. What mechanism do you suggest to sustain the amount of water in the Fogera wetland?

NGOs,NABU

1. What is your role on the wetland management in the BR of Fogera Woreda?
2. What is your organization's opinion on the conservation, sustainable use of wetland resources within the Fogera Woreda?
3. How does your office support the community to use wetlands resources in sustainable way?
4. What do you think on the sustainability of wetland resource conservation and use in the Fogera Woreda?

Association of Eth-wetland

1. What are the stakeholders that are working with your association?
2. How do you see the ecosystem services and functions that Fogera wetland has before the introduction of rice and after it?
3. What experiences do you have to manage wetlands according to Ramsar convention?
4. How your organization does work in collaboration with agriculture for sustaining wetlands of Fogera?
5. What are the roles and responsibilities of your organization regarding to Fogera wetland conservation and use?
6. Are there any policies and strategies regarding wetlands in the region and country?

Tourism Sector

1. What is the tourism activities practiced in Fogera Woreda (in BR)?
2. What support do you have for the tourism activities practiced in the area?
3. What advantages and disadvantages of tourism activities practiced in the area?
4. What do you suggest the potential tourism activities in the Fogera Woreda?
5. What do you suggest the linkages of sectors for sustaining Fogera wetlands?

APPENDIX II

Table 4.33 List of Type Plant species of the floodplain of Fogera in the study areas

	Scientific Name	Local Name	Scientific Name		Local Name
1	water hyacinth (Eicggornia crassipes)	Emboch arem	8	Cyperus spp	Engicha
2	Cuscuta spp	Yenug Anbesa	9	Commelina spp	Qimiza
3	Paspalum scrobiculatum	Gajja	10	Cynodon spp	Kibie Sar
4	Cynodon dactylon	Serdo	11	Cynodon spp	Akendabo
5	Ludwigia spp	Gaburda	12	Pennisetum thunbergii	Tucha
6	Ludwigia spp	Getetie	13	Pennisetum spp	Quaya
7	Cynodon spp	Chagua	14	Argemone achroleuca	Nech Lebash or Yeaheya Eshoh