

Linking Between Water Ecosystem Services' Perception and Rural Migration in Sahelian Wetlands: Evidence-based from Inner Niger Delta in Mali

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Abstract: Sahel's largest wetland, the Inner Niger Delta (IND) is highly productive with a biologically diverse ecosystem and fed by seasonal floods. It plays a crucial role in shaping culture and driving local and national economies. Over one million people composed mainly of fishermen, farmers, and breeders that depend on the vitality of these wetlands. Despite the resources that the IND contained, people continue to migrate to other countries. The main objective of this study is to analyze the link between water ecosystem services and the migration of IND's inhabitants. Specific objectives are to understand the endogen perception of ecosystem services and identify the determinants of migration outside wetlands. Based on recent household surveys including the econometric model, results show that 36.9% of respondents have at least one member who migrated out of IND. The remittances from migrants support 41.2% of respondents and 29.8% of them have the intention to migrate. The determinants of migration intention are gender, household size, land access, employment opportunities in livestock and fishing, submersion practice, soil fertility, peaceful natural resources management, credit access, migrated household members, and remittances from migrants. To limit migration, it is necessary to restore and conserve water ecosystems through innovations in climate change adaptation, integrated water resource management, and people sensitization towards nature-based solutions practices.

Keywords: Drought, Ecosystem Services, Household, Wetlands

1. Introduction

The wetlands are areas of marsh, fen, peatland, or water whether natural or artificial, permanent, or temporary with water that is static, flowing, fresh, brackish, or salt including areas of marine water, the depth at which low tide does not exceed six-meter [1, 2]. They cover about 6% of the world's

land surface with fundamental roles in the earth's system functioning through supporting biodiversity, storing carbon, fertile soils for agriculture, recharging groundwater table, removing pollutants, flood control, sediment, and nutrient retention [3, 5]. Their ecosystem services are crucial for sustaining rural livelihoods, especially in the developing world [6, 8].

In Africa, Wetlands are considered as the blue safety cords in the desert which are an important source of water and nutrients necessary for biological productivity and often sheer survival of people [9]. They have played a crucial role in shaping culture and driving local and regional economies for centuries through providing ecosystem and environmental services and thus supporting human livelihoods, especially where inland wetlands are extensively used for agriculture and as water sources [10]. According to a recent review of studies in Africa, there are 363 wetlands, excluding human-made wetlands, that provide 333 (92%) regulatory ecosystem services to people [2]. Of the wetlands that provide these services, 236 (71%) contribute to the maintenance of hydrological regimes, 233 (70%) to hazard reduction, 191 (57%) to erosion protection, 80 (24%) to climate regulation, 73 (22%) to pollution control and detoxification and 12 (4%) to biological control of pests and disease. In total, 341 wetlands (94%) provide cultural services, and supporting services are found in 125 wetlands (34%). The provisioning services included 336 (92%) of the wetlands. The review of studies on ecosystem services showed that provisioning services are the most common services in African wetlands [11, 12].

About 65% of the Wetlands resource within Sub-Saharan Africa is located within the four largest major basins; the Chad, Congo, Niger River, and Nile River basin [3]. In terms of areal representation, the Chad basin is the highest with wetlands constituting 10% of the surface area. While 26% of the freshwater marshes and floodplains and 27% of intermittent wetlands and lakes are located within the Chad basin, 95% of flooded and swamp forests are located within the Congo basin [13]. As biological diversity varies over geographic space the distribution of ecosystems is often examined in the context of biogeography, which describes the form and pattern of this spatial variation [14].

The Inner Niger Delta (IND) in Mali is the largest and most populous of inland wetlands in West Africa and ranks second only to the Okavango Delta in Botswana. Its area varies from 36,000 km² [15] to 80,000 km² [16]. According to [17] the northern part of the IND covers an area of 15,000 km² and the southern part 58,000 km². Similar discrepancies are reported for maximum flooded surface areas. Here, the values range between 10,000 and 20,000 km² [15] 10,000 and 45,000 km², and 15,000 km² [18]. The intensity of the flooding determines the discharge of Niger River and its tributaries including ecosystems and biodiversity.

The IND is recognized today as a wetland of international importance which was classified in February 2004 by UNESCO as a World Heritage Ramsar site for humanity. An area of 41,195 km² of the wetland was designated as a Ramsar site in 2004 by Mali [19]. It is a highly productive and biologically diverse ecosystem, fed by seasonal floods, and plays a crucial role in shaping culture and driving local and national economies. The IND has various native habitats (flooded forests and *Echinochloa stagnina* pasture) and hosts several endemic species: 112 species of water birds, 134 species of fish, and mammals such as hippopotamus and

manatees [13]. It is estimated that some 3–4 million waterbirds use the site as a wintering area. The global population trends of many waterbird populations are highly correlated with the ecology integrity of the delta wetland habitats including the river, lakes, flooded forests and *Echinochloa stagnina* fields [20].

The Delta covers just 1.6 percent of Mali, but it delivers 8% of its Gross Domestic Product (GDP) and sustains 14% of the population [21]. Most of two million people depend on it for their livelihoods through agriculture, fishing, and livestock production as well as for providing water and ecosystem services to millions living further downstream. It is estimated that the IND provides 30% of Mali's rice, 80% of national fish production, as well as dry season grazing for up to 60% of Mali's cattle. The flooding of the Delta is the engine of socioeconomic development as well as its ecological integrity [22]. When the waters recede, leaving behind damp and nutrient-rich sediments, farmers move into planting rice, millet, and other crops. Herders migrate with their cattle (out of the Delta) while fishermen follow the shifting waterfront. The return of the cattle into the IND is an important cultural ceremony for which no substitutes exist outside of the Delta. Temporary migration is routine among pastoralists who travel long distances to find fodder for their animals. Fishermen practice seasonal fishing migrations to find new fishing sites in the delta according to the lowering of flood levels [23]. Seasonal migration inside IND is a traditional strategy too for fishers, breeders, and farmers for adaptation to flood change including climate.

Despite the natural resources abundance in wetlands [20, 22], in recent years, people from IND like wetlands' local communities have often practiced migrating to drylands and cities of Mali as other countries [24]. Previous studies focused on migration into climate change and conflict, distinctly, without addressing ecosystem services [23, 25, 27]. The objective of this study is to analyze the link between water ecosystem services and migration in IND. Specific objectives are to understand the perception of ecosystem services and identify the determinants of migration outside IND. The methodological approach adopted for this study is based on recent household surveys including an econometric model for analyzing the link between ecosystem services and migration intention. The remainder of the paper is organized as follows. After describing the materials and methods, we present the results and discussions. The conclusions include some policy implications and research limits are provided in the last section.

2. Methodology

2.1. Study Areas

The study area is the IND in Mali which is in a semi-arid region in the Sahelian zone. It is a seasonally inundated floodplain, a network of tributaries, channels, swamps, and lakes providing vital habitats supporting livelihoods in fishing, farming, and stock farming for inhabitants [21].

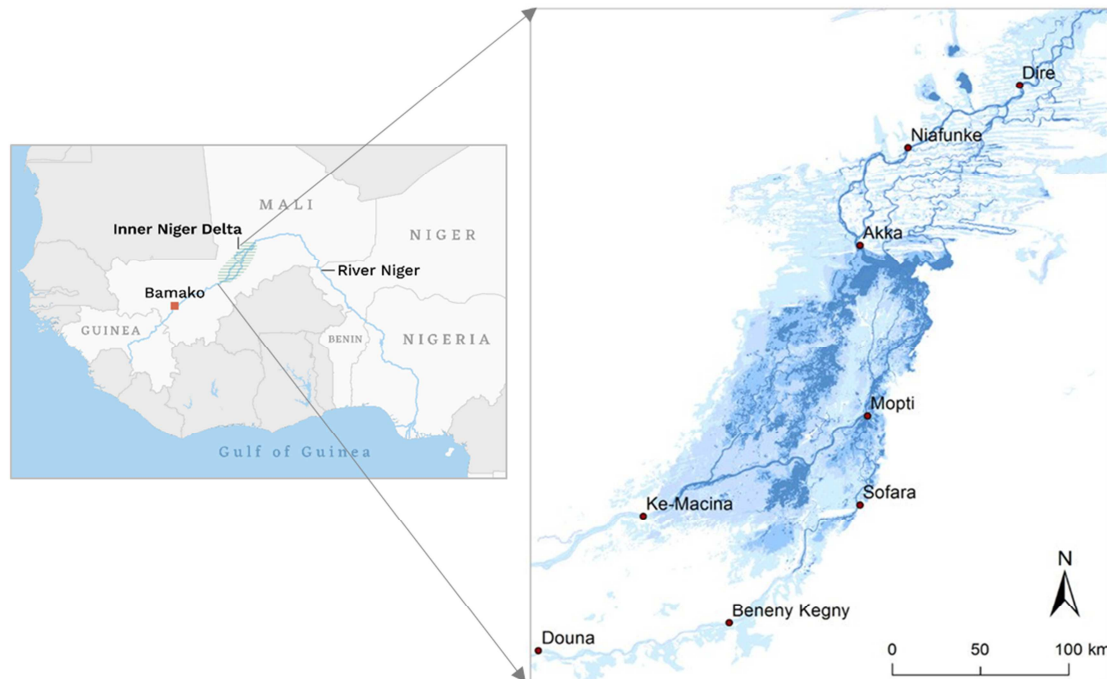


Figure 1. Location of Inner Niger Delta.

The annual inundation of the Inner Niger Delta floodplain with up to 4-5 m depth across a > 4 million ha floodplain, significantly influences the pattern of life in the IND, determining livestock migration patterns, agricultural practices, and food production cycles [22]. The “great droughts” of the 1970s and early 1980s, in conjunction with the development of the rivers upstream of the IND, with more planned to come, and water abstraction for formal irrigation schemes, have significantly affected the flow regime in the IND. Therefore, the spatial and temporal patterns of flooding and sedimentation processes in the IND have altered the ecosystem [28, 29]. These changes have negatively influenced the subsistence livelihoods of people living in the IND resulting in mass migrations to surrounding urban centers and into other countries, which are balanced by beneficial impacts resulting from these developments in the form of food security and formal employment associated with the irrigation schemes and other developments [9, 11].

2.2. Conceptual Framework

The ecosystems provide important services to inhabitants of IND and contribute to The Gross Domestic Product of Mali. However, inhabitants of IND like other people of Mali continue to migrate toward other areas [30, 31]. The willingness to migrate can be assimilated to a dichotomy variable - willingness to migrate or not – with explanatory variables [26, 32].

Several studies have analyzed the determinants of willingness to migrate using a logistic or probit model [25, 33, 26]. For example, Hogan and Steinnes (1998) used a logistic model to analyze households’ willingness to migrate in Arizona and Minnesota [34]. The results lead to the

conclusion that seasonal migration may be an integral part of the life cycle of elderly migration. Bertoli et al. (2022) used a multilevel approach to characterize the relationship between weather shocks and (internal and international) migration intentions [26]. Wondimagegnhu and Zeleke (2017) analyzed factors that determine rural communities’ decision to migrate to internal and international destinations in Habru district of Northeast Ethiopia [35]. Li and Samimi (2022) attempted to study the patterns and determinants of international migration and the cause and effects on sustainable development by developing a Sustainability Index and regression models [27]. Fassil and Mohammed (2017) examined the central characteristics of migrants and determinants of rural-urban migration in Southern Ethiopia based on snowball sampling and a survey of 665 sample migrants using descriptive and econometric analysis [36]. Olowa (2021) studied the determinant of migration and receipt of remittances by analyzing household data with the use of a multinomial logit regression model which allowed the decision to migrate and receive remittances [37].

The migration theory suggests that individuals initiate migration decision-making processes when they place utility moves from a positive to a negative state [38, 39]. The logistic model representing the households members’ intention to migrate or not is defined [40, 41]:

$$P = \Phi(\beta X_i) = \frac{\text{Exp}(\beta X_i)}{1 + \text{Exp}(\beta X_i)} \quad (1)$$

P is the dependent variable that takes 1 if household (i) is intention to migrate and otherwise 0, β is the vector of the parameters to be estimated, X_i is the explanatory variables and $\Phi(\beta X_i)$ is the probability that the household is intention to migrate.

In the Logistic model, the dependent variable represents the IND households' intention to migrate toward other Malian regions and countries. We considered the following independent variables: gender, households' size, land access, education, age, origin, employment opportunities in livestock, agriculture, and fishing, submersion practice, soil fertility,

peaceful in natural resources management, perception of fish availability in the river, and food security, credit access, migrated household' member and financial support from migrants (Table 1). The signs in the last column are hypothesized. These are the expected sign between the explanatory variables and the intention to migrate.

Table 1. Variables.

Variables	Description	Notation	Assumptions	Expected effect
Age	Age of the stakeholder	Yes: Older (age ≥ 40) No: otherwise	The older inhabitants may not migrate because their attachment to their community tends to be stronger than that of younger respondents [26, 41, 42].	-
Gender	Gender of stakeholder	Yes: Male No: Female	Age was expected to be negative for migration intention	-
Education	Education of stakeholder	Yes: the farmer is educated No: otherwise	Studies showed that men are more prone to migrate than women [43-45]. Be male influence positively intention to migrate	+
Size	Number of household members	Number	Education offers employment opportunities. If an inhabitant is educated, he will have more opportunities to seek a livelihood in a new place [42, 46]. Therefore, education is expected to be positive to migration intention.	+
Land	Land access	Yes: heritage No: Otherwise	Household size could shape migration aspirations. Larger-sized households have a higher number of individuals migrating internally or internationally [33]. It has a positive effect on migration aspirations.	+
Origin	Origin of respondents	Yes: Native No: Otherwise	Access to land by inheritance encourages local communities to remain sedentary to preserve the land heritage [47]. It affected migration outside IND	-
Agriculture	Employment in agriculture	Yes: Employment opportunities in the agriculture sector No: otherwise	Natives are more attached to their territory than foreigners [47]. Thus, they are thus less inclined to migrate than foreigners.	-
Fishing	Employment in fishing	Yes: Employment opportunities in fishing sector No: Otherwise	IND provides 30% of Mali's rice [22]. The opportunity of employment in the agriculture sector affects migration outside IND.	-
Livestock	Employment in livestock	Yes: Employment opportunities in the livestock sector No: Otherwise	IND insures 80% of national fish production [22]. The opportunity of employment in fish sector affects migration outside IND.	-
Submersion	Submersion practice	Yes: Practicing submersion agriculture No: Otherwise	Livestock is an indicator of wealth [35]. The opportunity of employment in the fish sector affects migration.	-
Fertility	Perception of soil fertilization through flood	Yes: Soil fertilization through flood No: Otherwise	The practice of irrigating crops by flooding relieves farmers of the costs associated with irrigation (equipment, drilling, water storage basins, etc.) [28].	-
Fish	Perception of fish availability	Yes: Fish availably No: Otherwise	The rising and falling waters make it possible to fertilize the agricultural soils. This natural soil fertilization reduces the use of chemical fertilizers and related expenses.	+
Fodder	Perception of fodder availability for cattle	Yes: fodder availability No: Otherwise	In IND, fishery is a traditional and cultural activities which provides 80% of national fish production. More than half of the total production is auto-consumption in IND [21]. The availability of fish affected migration.	-
Peace	Peaceful management of natural resources	Yes: Living in peaceful management of natural resource No: Otherwise	Bourgou grass is considered very suitable for livestock rearing and breeding [20]. A total of 2 million cattle and 5 million small ruminants thrive and are bred within the IND. The availability of <i>bourgou</i> for livestock affected migration.	-
Food	Food insecurity	Yes: vulnerable to inundation No: Otherwise	The peaceful management of natural resources avoids conflicts between stakeholders and allows them to settle in the IND [48]. It avoids migration outside IND.	+
Credit	Access to credit	Yes: Credit access No: Otherwise	Despite the abundance of ecosystem services in IND, insurance food security is a challenge for inhabitants [49]. Food insecurity incites inhabitants to migrate	+
Migrant	Members of households already migrated	Yes: Migration of households' members No: Otherwise	Inhabitants in IND have difficulty with credit accessibility to invest in their activities [50]. Credit inaccessibility positively influences migration.	+
Support	Financial support from migrants	Yes: Receive remittances No: Otherwise	Migration is cultural practice for certain communities [51]. For this reason, migrants incited their households' members migrate.	+
			Migrants financially support their parents stay in Mali [52]. This support positively influence migration.	+

2.3. Data Collection

This study is based on 1225 households' random survey from 60 villages at 12 municipalities in IND. The survey was conducted in Mopti and Segou regions in Mali. A survey questionnaire was prepared and administered by trained enumerators who collected data from households through personal interviews. Questionnaires were translated into the

local languages and were pre-tested and adjusted slightly to better match the specific conditions of both case studies prior to their use. Enumerators were trained to probe when appropriate. The collected data concerned household socio-demographic characteristics, number of migrants in the households, perception of water ecosystem services, security issues and migration.

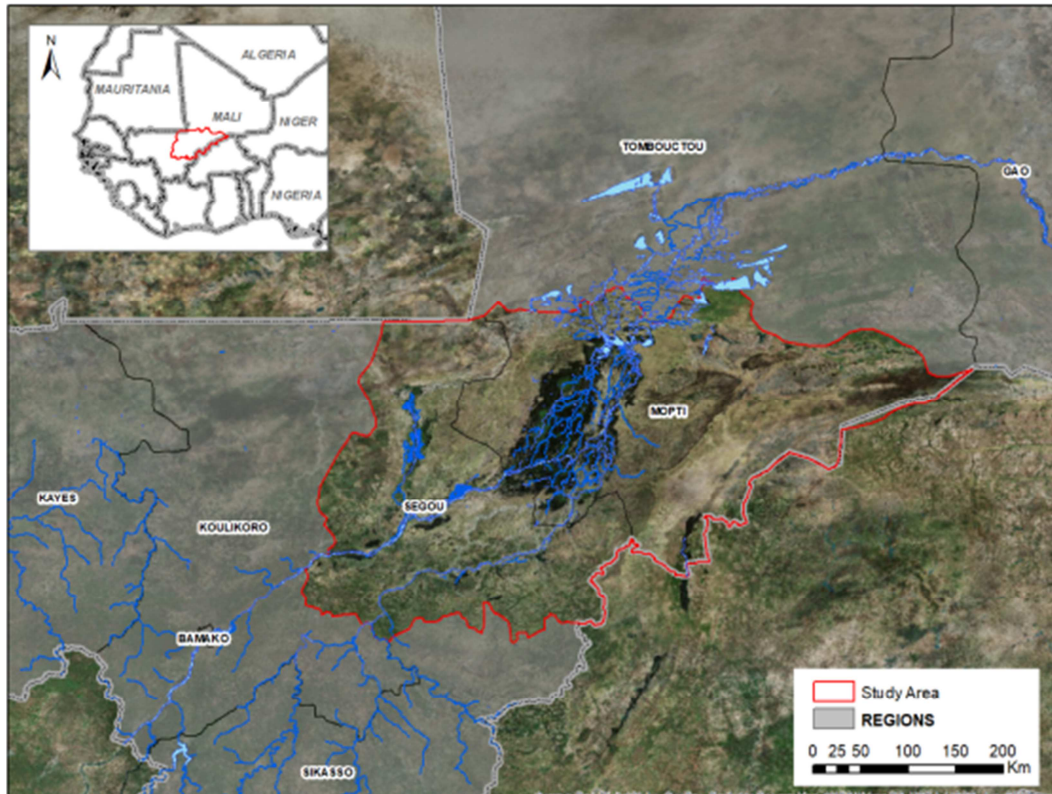


Figure 2. Study area in Inner Niger Delta.

3. Results and Discussions

3.1. Socio-Economic Characteristics

The socio-economics characteristic of surveyed inhabitants' sample relates to gender, age, education, household size, origin, land access mode, main activities, food security, human security, and unemployment in agriculture, fishing, and livestock sectors (table 1). The surveyed sample is majority composed of men (93.5%), illiterates (59.7%), and adults more than 40 years (80.5%). It is constituted by 97.3% and 2.3% of natives and immigrated people, respectively. The

inhabitants practice simultaneously agriculture, livestock, and fishing. But unemployment is a major concern in IND. In agriculture and livestock sectors, unemployment is perceived by 46.6% and 48.8%, respectively, by the sample surveyed inhabitants. However, it is less crucial in the fishing sector. Only 23.5% of inhabitants mentioned the unemployment. Food insecurity touched 15.9% of surveyed inhabitants because they take less than 3 meals per day. According to 37.1% of inhabitants, natural resources exploitation generates conflicts between people. The land access is by inheritance for 82.6% of the surveyed sample.

Table 2. Socioeconomic characteristics of surveyed sample.

Socio-economic characteristic	Frequency	Percent	Mean	Standard deviation
Gender				
Female	79	6.5		
Male	1138	93.5		
Size			15	6.4
Age				
< 40	237	19.5		

Socio-economic characteristic	Frequency	Percent	Mean	Standard deviation
≥ 40	980	80.5		
Education				
Illiterate	727	59.7		
Literate	490	40.3		
Origin				
Native	1189	97.7		
Migrant	28	2.3		
Land				
No	168	13.8		
Heritage	1049	86.2		
Agriculture				
No	652	53.6		
Yes	565	46.4		
Livestock				
No	623	51.2		
Yes	594	48.8		
Fishing				
No	283	23.3		
Yes	934	76.7		
Food				
No	1024	84.1		
Yes	193	15.9		
Credit				
No	709	58.3		
Yes	508	41.7		
Peace				
No	452	37.1		
Yes	765	62.9		

3.2. Local Perception of Water Ecosystem Services

The IND offers several ecosystems to the inhabitants. The perceptions of inhabitants' sample are focus on flood, submersion of crops' practice, soils fertility, fodder, and fish (Table 2).

According to 85.5% of respondents, the practice of submersion rice through flood and low water is an ecosystem service. It is an alternative to irrigation by diesel pumping with consequences pollution of water and soil. Farmers cultivate an area ranging from 50,000 to 130,000 ha of deep-water rice with yields generally below 1 ton/ha [15].

For 56.3% of respondents, soil fertility is also another ecosystem service. Soil fertility is improved through flood followed by low water level. With improving of soil fertility, farmers rarely buy chemical fertilizers for fertilizing lands [22].

Bourgou (*Echinochloa stagnina*) is fodder that is assimilated to an ecosystem service by 98.3% of respondents. The optimal habitat for bourgou is water about 4-5 m deep [53]. The livestock production is linked to the availability of Bourgou grass which is considered very suitable for livestock rearing and breeding (Marblé, 2008). More than 2 million cattle and 5 million small ruminants thrive and are bred within the IND. In addition to being grazing areas, fields of *Echinochloa stagnina* are spawning grounds for fish and serve as habitats for many species of waterbirds. There are more than 100,000 birds of 15 different species and 70 species of fish in IND. Bourgou is intended to support the fisheries of the delta to provide 50 -100 000 t/fish/ year [15].

Fish is perceived by 98.5% of respondents as an ecosystem service. It is permanently captured during the year. However,

abundance of captures is observed between March and April depending on IND's areas. These captured represents 80% of national fish production and are essentially destined to Malian's consumption. Less than 15% of fish production is exported to West African countries, especially Burkina Faso and Niger.

Table 3. Perception of ecosystem services.

Ecosystem services	Frequency	Percent
Submersion		
No	176	14.5
Yes	1041	85.5
Fertility		
No	1004	82.5
Yes	213	17.5
Fodder		
No	21	1.7
Yes	1196	98.3
Fish		
No	20	1.6
Yes	1197	98.4

3.3. Migration Practices

Table 4 shows migration practices in IND. The analysis showed that 36.9% of the sample have at least one member who migrated out of IND. The main destinations of migrants are Malian cities, African countries, and others such as Europe, Canada, and United States of America [31]. Financial support from migrants is received by 41.2% of rested of the surveyed inhabitants. The remittances from migrants play for the development of Mali [54]. They contribute to reduce poverty, and food insecurity and increase economic [55]. Despite the abundance of ecosystem services which are already contributed to Malian's economic [9, 56], the results show that 29.8% of the

surveyed sample are intention to migrate out of IND in the next five year. This result is supported by studies of [26] which find that migration intention varies between 20% and 56% in the next 12 months in West-Africa. The migration intention is general in many wetlands in developing countries [57].

Table 4. Migration practices.

Migration practices	Frequency	Percent
Household' member migrated out of IND		
No	768	63.1
Yes	449	36.9
Financial support by migrants		
No	715	58.8
Yes	502	41.2
WTM		
No	854	70.2
Yes	363	29.8

3.4. Determinants of Intention to Migrate

Water ecosystems provide important services to the people of IND but a part of them have the intention to migrate. Stepwise binary logistic regression is employed to estimate determinants of intention to migrate which are gender, households' size, land access, employment opportunities in livestock and fishing, submersion practice, soil fertility, peaceful in natural resources management, credit access, migrated household' member, and financial support from migrants (table 5). The factors with positive sign coefficients promote migration contrary to those have a negative sign coefficient. Education, age, origin, perception of fish availability in the river, opportunity of employment in agriculture, and food security are not influencing the intention to migrate outside IND.

Table 5. Determinants of intention to migrate.

Determinants	Coefficients	Standard Error	z	P>z
Age	-0.284844	0.20536	-1.39	0.165
Genre**	1.346702	0.45406	2.97	0.003
Education	0.112661	0.17107	0.66	0.510
Size**	0.065907	0.02160	3.05	0.002
Land access*	1.351530	0.30177	4.48	0.000
Origin	-0.393731	0.70618	-0.56	0.577
Agriculture	-0.584179	0.48236	-1.21	0.226
Fishing***	-2.371257	0.89634	-2.65	0.008
Livestock**	-2.367709	0.75939	-3.12	0.002
Submersion*	-1.789190	0.23631	-7.57	0.000
Fertility*	-0.930882	0.25327	-3.68	0.000
Fish	-0.038396	0.78843	-0.05	0.961
Fodder	0.644487	0.63645	1.01	0.311
Peace*	-0.705822	0.17796	-3.97	0.000
Food	0.124370	0.21475	0.58	0.563
Credit*	2.337942	0.18403	12.70	0.000
Migrant***	0.385608	0.20126	1.92	0.055
Support*	-0.718048	0.19630	-3.66	0.000
Constant	-3.124947	1.31547	-2.38	0.018
Number of observations	= 1217			
LR chi2 (18)	= 510.71			
Prob > chi2	= 0.0000			
Pseudo R2	= 0.3443			
Log-likelihood	= -486.2797			

**, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively

The variables gender, households' size, land access, credit access, and migrated household's member positively influence willingness to migrate. The men are more willing to migrate than women. They are households' heads and oversee assure the livelihood of members [58, 33]. Inaccessibility to land and credit incite people to search for opportunities out of IND as having a migrating family member. In IND, human pressure and traditional governance are the sources of inaccessibility to land [59]. Such context forces people to migrate for finding arable lands. Microfinance institutions are practically nonexistent. Financial access is a challenge for inhabitants. Having a migrated household member influence positively intention to migrate outside IND. Similar results were shown in previous studies [42, 58].

The variables which affected the intention to migrate are employment opportunities in livestock and fishing,

submersion practice, soil fertility, peaceful in natural resources management and financial support from migrants. Fishing and livestock practices are traditional activities in IND [23]. The opportunities in terms of employment in the fishing and livestock sectors are an alternative to migration because it allows to generate income and improve food security. The possibility to practice animal husbandry limits also the intention to migrate outside of IND. Animal husbandry is a cultural identity for inhabitants. To maintain this identity, inhabitants are not willing to migrate. When inhabitants feel safe, they do not move outside IND which is rich in terms of ecosystem services [60]. Soil fertility is an ecosystem service that reduce cost of purchasing mineral fertilizers. It encourages people to stay in IND as it reduces agricultural expenditure. Flood embedment is another ecosystem service which avoids the destruction of homes, and crops, and protects

inhabitants against deadly damage. It allows inhabitants to secure their livelihoods and maintain them in IND [22, 50]. The remittances support people in origin countries of migrants [58]. In IND, beneficiaries of these remittances renounce migration insofar as they are responsible for caring of the family. Similar observations were made by [33] which findings showed that beneficiaries of substantial remittances are not willing to migrate.

4. Conclusion and Policy Implications

Water ecosystems provide several services to the people of IND. The surveyed respondents' perception of ecosystem services is focused on fish, fodder (*Echinochloa stagnina*), soil fertility, and irrigation through submersion. These ecosystem services ensure the livelihood and income of inhabitants. Despite the abundance of ecosystem services, 36.9% of respondents have at least one member who migrated out of IND. The remittances from migrants support 41.2% of respondents. The study showed that 29.8% of the surveyed sample have intention to migrate. The determinants of intention migration are gender, households' size, land access, employment opportunities in livestock and fishing, submersion practice, soil fertility, peaceful natural resources management, credit access, migrated household member, and remittances from migrants. The intention to migrate outside IND is affected by employment opportunities in livestock and fishing, submersion practice, soil fertility, peace in natural resources management, and financial support from migrants. However, it is positively influenced by gender, households' size, land access, credit access; and migrated household's member positively influence willingness to migrate. The restoration and conservation of water ecosystem through innovations in climate adaptation, integrated water resource management and people sensitization could limit migration in IND. The study merits to be deepened by integrating other contextual factors such as climate change, human peace, armed conflicts, and violence.

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