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Economic Valuation of Ecosystem Services in Sahel's Wetlands: Case of Bourgou (Echinochloa stagnina) in the Inner Niger Delta

Beteo Zongo[1 *] Mori Diallo[2] Karounga Keïta[2] Abdouramane Djibo Gado[3] Omer S. Combary[4] Patrice Toé[5] Thomas Dogot[6]

1. University of Dedougou, 03 P. Box BP 176 Dedougou 03, Burkina Faso
2. Wetlands International Sahel, P. Box 517, Hamedallaye ACI 2000, Bamako, Mali
3. Red Cross Red Crescent Climate Centre, The Hague, the Netherlands
4. Department of Economics and Management, University Ouaga 2, Burkina Faso
5. Institute for Rural Development, University Nazi Boni, 01 P. Box 1091 Bobo Dioulasso 01, Burkina Faso
6. University of Liege, Rural Development and Economic United, Gembloux Agro-Bio Tech, P. Box 5030, Gembloux, Belgium

* E-mail of the corresponding author: beteozongo@yahoo.fr

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Abstract

The Inner Niger Delta (IND) located in Mali provides several ecosystem services to Sahelian people. Among these services, the bourgou fields (*Echinochloa stagnina*) have a very high value for inhabitants' livelihood and biodiversity. The main objective of this study is to assess the economic value of bourgou ecosystem services in the IND. Specific objectives are to analyze ecosystem services from *Echinochloa stagnina* and the benefit-cost of its regeneration (plantation) in the IND. The adopted methodology is based on market price and benefit-cost approaches through analysis of collected data from conducted inhabitants' surveys in the circle of Youwarou located in Mali center. The findings show that each Bourgou producer farms on average 7 hectares that provide fish, pasture, livelihoods, and habitats for biodiversity as ecosystem services. The revenue received by bourgou producers with payment for access to pasture for 89,347 cattle is estimated at USD 150,674.78 (47,085,869 FCFA). The benefit of ecosystem services from bourgou is USD/ha 999.22 (312,257 FCFA/ha). To restore bourgou fields, 98.5% of producers are willing to pay USD 192.07 (60,023 FCFA) for it to improve seeds of 1 hectare cultivation. The bourgou culture is a green financing opportunity for income generation, ecosystem services restoration, and biodiversity conservation.

Keywords: Bourgou, Biodiversity, Ecosystem services, Income, Inner Niger Delta
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1. Introduction

The Inner Niger Delta (IND) is a continental wetland designated as a Ramsar site in 2004 by Mali (Ramsar, 2004). It is the largest inland wetland in West Africa and the second largest wetland in Africa, after the Okavanga Delta in Botswana. It includes a network of river channels with levees and low-lying interdistributary floodplains that support permanent and seasonal lakes and ponds (Thompson et al., 2017). The key feature of the delta is the annual flood, which reaches a peak between August in the southwest and January in the northeast (Zwarts and Diallo 2002). Starting in July, the water rises about 4 m in 100 days (Mahe et al., 2013). In years of high river discharge, the water level in the peak period may be 6 m higher than a few months earlier. The interannual differences in flooding make the system even more dynamic (O'brien et al., 2020). In a year with a high peak flood level in the Inner Delta, the flood lasts four months longer than in a year with a low flood: the wave comes in a wet year one month earlier and continues for an additional three months. When the water level starts to rise in July in the southwestern part of the Delta, the plains in the northeast are still dry. By the time the northern plains become flooded two months later, the water level is already declining in the south (Zwarts et al., 2005).

With an area of 41,195 km2, the IND plays a fundamental role in the economic growth and livelihood of people by providing ecosystem services (Ogilvie et al., 2010; Schroeder et al., 2012). It is crucial for the livelihoods of 1.5 million people (herders, fishermen, and crop farmers), many of whom are entirely dependent on the Delta's natural resources (Zare et al., 2017; Acosta-Alba et al., 2022). Dominant ethnic groups include semi-nomadic Peul cattle herders, Bambara and Marka traditional crop producers, and Bozo and Somono fishers (Zwarts et al., 2006; Morand et al., 2012). The IND is a concentration of human activities: agriculture, farming, fishing, crop, navigation, and tourism (Zwarts et al., 2005). It supports the largest fishery in Mali, providing more than 90% of the national catch and exports to Niger and Burkina Faso (Zwarts et al., 2005).

A previous study assessed the ecosystem services of the IND and highlights its cultural importance to the inhabitants as their livelihood depends on the provided services as well as its importance for biodiversity (Rebelo et al., 2013). The bourgou (*Echinocloa stagnina*) is the key species that provides ecosystem services and has

therefore a very high value for inhabitants' livelihood and biodiversity (Sultanian & Van Beukering, 2008). Bourgou contributes to food security and income of inhabitants who consume and sell its grain and juice (Benjaminsen, 1993). Inhabitants harvest and sell it fodder (Charancle, 1994; Coppock & Desta, 2007).

Bourgou is growing in flooded fields in depths between 4 and 6 meters (Zwarts et al., 2005). They are spawning grounds for fish reproduction (Acosta-Alba et al., 2022). During flooding, fish species laterally migrated from the Niger River and reproduced in bourgou fields (Oyebande, 2002). They return to Niger River to grow during low water in the bourgou fields. Fish migrations include both lateral movements onto floodplains and long-distance, longitudinal movements. There is anecdotal evidence of several fish moving as much as 440-640 km up the Niger River into the IND with the onset of floods (Welcomme et al., 2010). The captured fish (Ramsar, 2004), provided more than 90% of the national catch (African Bank Development, 2004; Morand et al., 2012).

In addition to being spawning grounds for fish, Bourgou fields serve as habitat for many species of waterbirds, and mammals such as hippopotamus and manatee (Cappelle et al., 2010). Previous studies indicated 112 species of waterbirds in IND (Ramsar, 2004). Bourgou fields constituted winter quarters for millions of species of intercontinental migratory waterbirds (Kone et al., 2007). Inhabitants improve their food security and income through the consumption and trade of waterbirds (Sultanian & Van Beukering, 2008).

The IND plays a major role in the livestock sector of Mali thanks to provision of pasture by the Bourgou fields (Coppock & Desta, 2007; Balehegn et al., 2022). It concentrates 60% of national cattle from Mali (Kone et al., 2011). During the dry season, Bourgou fields are converted into pastures for cattle (Ousmane et al., 2019). The transhumant herders pay Bourgou field owners for their cattle's access to pastures (Zwarts et al., 2005).

Despite the importance of Bourgou as an ecosystem service, its economic value has not yet been addressed in the literature. Previous studies are focused on waterbirds (Cappelle et al., 2010; Kone et al., 2007), fish, integrated water management (Rebelo et al., 2013; Yang et al., 2018), flood forecast (Zare et al., 2017), environmental flow (O'brien et al., 2020), agriculture (Liersch et al., 2013), flood (Thompson et al., 2017). The main objective of this study is to assess the economic value of *Echinochloa stagnina* in the IND. Specific objectives are to analyze ecosystem services from *Echinochloa stagnina* and the benefit-cost of its regeneration (plantation) in the Inner Niger Delta center. The adopted methodology is based on the market price and a benefit-cost approach analysis approached through analysis of collected data from conducted inhabitants' surveys in the circle of Youwarou located in Mali center.

2. Materials and methods

2.1. Study area

The study is conducted in the subdivision Youwarou Circle located in the Mopti region in Mali. The climate is semi-arid (due to its location in the Sahel) with rainfall ranging between 200 and 400 mm per year. The hydrological system of Youwarou Circle is made up of Niger River stream with numerous lakes and ponds. The flood begins in July and reaches its maximum level in November. In January the plains are completely submerged and with them the various ponds in the area. This entire hydrological network retains large quantities which are the main potentialities for all the economic activities of the Circle: agriculture, livestock, fishing, transport, and trade.

Agricultural production is generally intended for family consumption and does not cover the food needs of most households. The livestock sector occupies a prominent place in the local economy. It is punctuated by the seasons and the state of resources; in the rainy season, the resources used are exposed pastures and ponds across pastoral tracks. In the dry season, the animals are taken to flooded areas rich in bourgou, access to which is subject to payment by the owners of rights to the bourgou managers (Ousmane et al., 2019). Fishing is a main economic activity practiced by the inhabitants. In a normal flood year, the catch of fish is very high. It is governed by water masters and subject to conditions of access which give a right of precedence to indigenous fishermen. The fish is sold fresh or after processing in various forms: smoked, burnt, or dried. More than 50% of fish is sold in local markets (Zwarts et al., 2005; Morand et al., 2012).

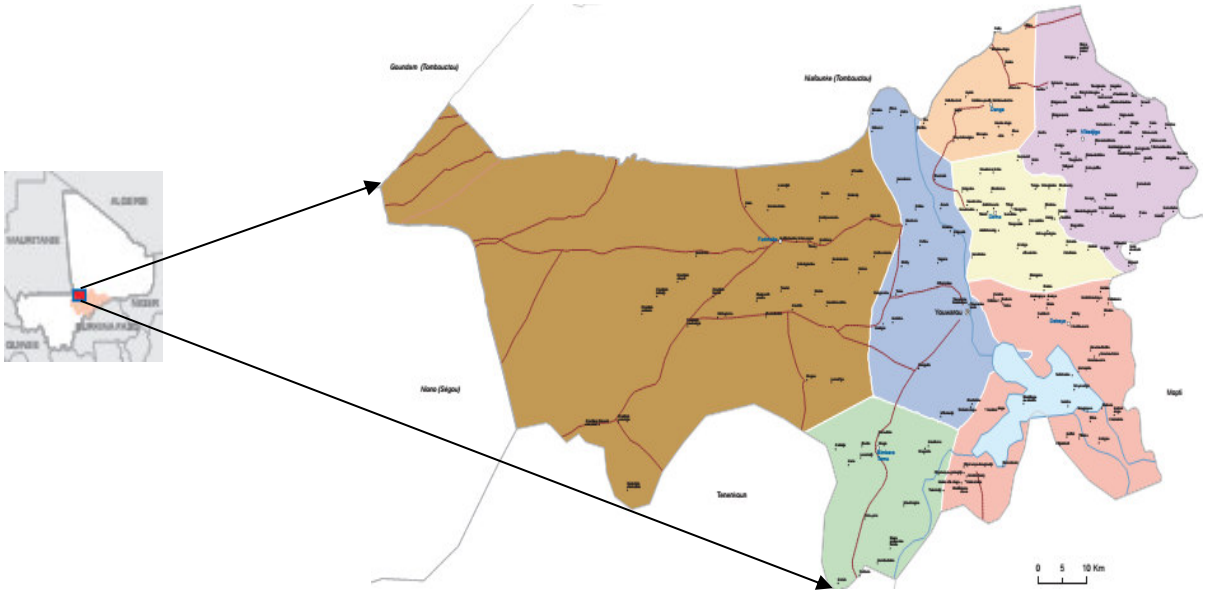

Figure 1. Map of Youwarou Circle in Mali

2.2. Data collection and analysis

The data was collected by enumerators from a sample of 200 bourgou producers in 12 villages distributed in Youwarou and Deboye municipalities of Youwarou circle. The structured questionnaire contained different sections which collected data on farmer and farm characteristics such as cultivated areas, number of cattle, fodder, data on biodiversity (occurrence of birds, fish, hippos), economic data such as payment for pasture access, and the income generated, quantity of captured fish, price (fish, fodder) and finally data on farmers' attitude such as their willingness for planting bourgou.

Table 1. Sites of data collection in IND

Circle	Municipalities	Villages	Surveyed sample
Youwarou	Deboye	Akka	24
		Bella Daga	12
		Feroibe	15
		Nogoukoto	14
		Tialde	5
		Total Deboye	70
	Youwarou	Serakourou	25
		Tassekoarou	13
		Tiadal Pouri	20
		Hombolore	39
		Lalabonfarande	3
		Ouro	27
		Djonde	2
		Total Youwarou	130
Total			200

Descriptive statistics are used to analyze socioeconomic characteristics of populations and ecosystem service. Economic value (EV) of ecosystem services is estimated through cost-benefit analysis (MEA, 2005) (M.Cui, Zhou, & Huang, 2012) (Wangai, Burkhard, & Müller, 2016). The components of cost are charges for the purchase of bourgou cuttings (BC) and labor for their planting (PC). Receipts are from payments for access to pasture (AC), sale of bourgou grain (SB), fodder (SF) and captured fish (CF).

$$EV = (AC + SB + SF + CF) - (BC + PC)$$

3. Results and discussion

3.1. Socio-economic characteristics

The profile of bourgou producers is established based on the main activities practiced in the study area (table 1). On this basis, data analysis show that the sample of bourgou producers surveyed is made up of 65% fishermen,

18% farmers and 16.5% breeders. Fishermen are in the majority among the producers of bourgou sampled. Two ethnic groups, the Bozos and the Somonos, are the primary fishermen in the IND (Morand et al., 2012). However, the management of bourgou fields is ensuring by authority of a person called the "dioro" (Coppock & Desta, 2007).

The status of bourgou producers is based on the mode of access to land in the bourgou production area. It shows that 96% of the sample inherited the bourgou fields. Only 4% of bourgou producers have lent the production area. The heirs of the bourgou fields are the owners of the production areas. The majority of the bourgou fields are privately owned and managed under the traditional djoro management system. This management system originated in the "Dina" code established in 1818 by Sekou Ahamdou (Coppock & Desta, 2007).

The total area devoted to bourgou fields is estimated at 1454 ha for the sample of producers surveyed. On average, each bourgou producer farms 7 ha. The minimum and maximum areas exploited are 1 and 50 ha respectively. The standard deviation shows a significant variation in surface areas between bourgou producers (standard deviation > mean). Each breeder, fisher, and farmer farms on average 3 ha, 10 ha and 2 ha respectively. Most of the area is exploited by fishermen (88%).

Table 2. Profile of sampled bourgou producers

Characteristics	**Percent**	**Area in hectares**
Bourgou producers		
Breeders	16.5	
Fishermen	65.5	
Farmers	18.0	
Status of bourgou producers		
Owners and managers	96	
Operators	4	
Exploited areas of bourgou		
Breeders	7	102
Fishers	88	1280
Farmers	5	73

3.2 Ecosystem services

Bourgou production is mainly intended for livestock feed. Due to its high importance as fodder, the bourgou fields' coverage can be seen as an indicator for the number of livestock (Zwarts et al., 2005). This relationship is based on the extension of the flooded area during the rainy season and the ability of the flood to provide a suitable habitat for certain grazing grasses. Once the delta flood begins to recede, these pastures become available for livestock. According to Bourgou producers, 179,172 cattle (143,337.6 TLU) grazed in the bourgou fields (Table 3). The number of Tropical Livestock Unit (TLU) is on the 1454 ha estimated at 98.6 TLU/ha. This result corroborates with those of the National Directorate of Nature Conservation, approximately 5 million cattle are invested each year in the delta, more particularly its bourgou fields (Dakouo, 2010). The exceptional value of bourgou does not lie only in the nutritional quality of fodder but also in the determining role it plays in regulating the ecology of the Delta, in terms of nesting and feeding fish and the fixing the silt and soil.

Cattle's access to grazing in the bourgou fields is governed by rules established by the local communities, including payment or not (Charancle, 1994). Nearly 83.5% of bourgou producers indicated that the cattle grazed on their farms without payment but respecting social rules (Table 3). These bourgou producers are the owners of the cattle grazing without payment. However, 16.5% of bourgou producers benefited from a payment of 527 FCFA[1/]cattle before grazing for 4 months. In total, the revenue received by these Bourgou producers from the grazing of 89,347 cattle is estimated at 47,085,869 FCFA. The extrapolation of the payment for grazing to the 179,172 cattle in the sample generated revenues estimated at 94,423,644 FCFA.

Mowing bourgou is a practice observed in the IND. About 64.3% of bourgou producers mowed bourgou to sell. The number of bundles harvested (fresh weight = 6 kg) is estimated at 1,327,701. Revenue generated by mowing bourgou is estimated at 271,472,612 FCFA. Bourgou seeds are harvested from a few bourgou producers (1%). The quantity of seed harvested is estimated at 52 kg. The revenue is estimated at 83,200 FCA.

The bourgou fields are areas of reproduction and development of fish. Most of the surveyed sample (98%) indicates that fishing is practiced in the bourgou fields. The quantity of fish caught is estimated at 442.445 T. With an average selling price of 760 FCFA/kg at the local level, the revenue generated is estimated at

[1] Five hundred francs CFA is worth 1.61 dollars.

336,340,134 FCFA. In total about 130 different species of fish are found in the IND, but few species are endemic because times the Niger River was linked to the Chad and Nile systems at various historic times (Lowe-Mcconnell, 1985). Two of the near-endemic fish species found here are *Syndodontis gobroni* and *Gobiocichla wonderi.* Many species migrate upriver and downriver as well as laterally out on to the floodplain as the water rises (Quensière & Poncet, 2018). When the flood recedes, the fish move upriver and two deeper parts in the river. Also, fish are trapped in small, isolated ponds (mares), where they are caught by local communities. Some fish species can survive in these dwindling pools by aestivating or by breathing air (Lowe-Mcconnell, 1985).

The bourgou fields are areas of attraction for birds, indicators for measuring the health of wetlands. Bourgou habitats are of major importance for populations of several resident and migratory bird species, including herons and egrets (Zwarts et al., 2005). The abundance of waterbirds was observed by 95% of bourgou producers. The avifauna comprises species which are piscivorous (herons, cormorants, terns), benthivorous and omnivorous (waders, ibises) and insectivorous (some plover species, wagtails), besides a few seed-eating species (mainly ducks). This means, that waterbirds are involved in most links of the food web in the floodplain.

Hippos (*Hyppopotamus amphibus*) are among the indicators for measuring wetland health (Adekola & Mitchell, 2011). They were seen by 98.5% of bourgou producers. Each bourgou producer saw an average of 9 hippos on their farm. In principal Hippos visit al flooded parts of the floodplain, depending on the height of the flood. They appear more often in the deeper parts when the flood recedes.

Table 3. Grazing and biodiversity in the bourgou fields

Designation	**Value**
Number of cattle (cattle)	179,172
Number of TBU (TBU)	143,337.6
Area (ha)	1,454
Density (TBU/ha)	98.6
Payment for access to bourgou (%)	
Yes	83.5
No	16.5
Number of cattle paying for grazing (cattle)	89,347
Average duration of grazing (months)	4
Average amount (FCFA/cattle)	527
Recipe from grazing generated (FCFA)	47,085,869
Number of cattle in the sample (cattle)	179,172
Pasture recipe with the number of cattle in the sample (FCFA)	94,423,644
Bourgou harvesting (%)	
Yes	64.3
No	35.7
Number of bundles harvested (bunch)	1,327,701
Average fresh weight per bunch (kg)	6
Average selling price per bunch (FCFA/boot)	212
Hay revenue (FCFA)	271,472,612
Seed harvest (%)	
Yes	1
No	99
Seed quantity (kg)	52
Selling price (FCFA/kg)	1,600
Seed recipe (FCFA)	83,200
Captured fish (%)	
No	2.0
Yes	98.0
Quantity of fish caught (kg)	442,445
Selling price of fish (FCFA/Kg)	760
Fish recipes (FCFA)	336,340,134
Waterbirds in the bourgou fields (%)	
No	4.2
Yes	95.8
Hippos in the bourgou fields (%)	
No	1.5
Yes	98.5

3.3. Economic value

Table 4 shows economic value of bourgou ecosystem services. Bourgou culture generates costs related to the purchase of seeds and the mobilization of labor for transplanting. The cost of 100 ha of bourgou is estimated at 17,076,885 FCFA. This means a charge of 170,768.85 FCFA/ha. The regeneration of 1454 ha costs 248,297,908 FCFA. Revenues per 1454 ha of bourgou culture are estimated at 702,319,590 FCFA. Thus, the income generated by 1454 ha is 248,297,908 FCFA, i.e., 312,257 FCFA/ha. However, the revenue is not distributed equally: "djoros" are getting increasingly rich while other actors stay poor (Cotula & Cissé, 2006). Herders must pay "djoros" to get access to bourgou fields. There are also rules about who gets access first. Next to the fields managed by the "djoros" and used for transhumance, there are comminatory bourgou fields called the "Harima" which are used to feed cows and oxen that are staying during the whole year in that area instead of transhumance grazing (Coppock & Desta, 2007).

In addition to monetary income, the benefits of bourgou regeneration are truly the restoration and conservation of biodiversity. The bourgou fields constitute the habitat of numerous wildlife species (fish, birds, hippos, etc.). They are spawning grounds for fish and nesting areas for waterbirds (Hamerlynck et al., 2016). They make it possible to fertilize the soil for farming after the flood has receded (Schroeder et al., 2012).

Table 4. Cost-benefit of regenerating bourgou fields

Designation	**Amount (in FCFA)**
Payment for access to bourgou pastures	94,423,644
Captured fish	336,340,134
Fodder of bourgou	271,472,612
Bourgou grain	83,200
Recipes	702,319,590
Charges (cuttings and labor)	248,297,908
Economic value	454,021, 682
Economic value/ha	312,257
Economic value /producer	227,011

3.4. Willingness to pay for bourgou restoration

Bourgou offers many benefits to local communities (Coppock & Desta, 2007; Zare et al., 2017). However, bourgou fields suffer degradation due to passage of animals and diminishing space for their cultivation – due to expansion of rice production and the conjugated effects of climate change and infrastructure decision that led to a diminishing of the flooded zone and water availability (O'brien et al., 2020). Since the 1950s about 25% of the bourgou fields in the IND have been converted into rice fields – partially as a response to climate change and partially because of policy priorities (Leauthaud et al., 2019). It is estimated that only two-thirds of historical Bourgou growing areas are still productive (Rebelo et al., 2013; O'brien et al., 2020).

To restore bourgou fields, 98.5% of producers agree to pay for the regeneration of bourgou fields. This willingness to pay denotes the interest given to the regeneration of the bourgou by the local communities (Marble, 2008). The average willingness to pay for 1 ha of bourgou fields is 64,023 FCFA with a minimum of 8,000 FCFA, a maximum 150,000 FCFA and a standard deviation of 25,631. Considering the price of a kg of seed at 1,600 FCFA, the bourgou fields agree to pay 93.75 kg of seed for 1 ha of bourgou.

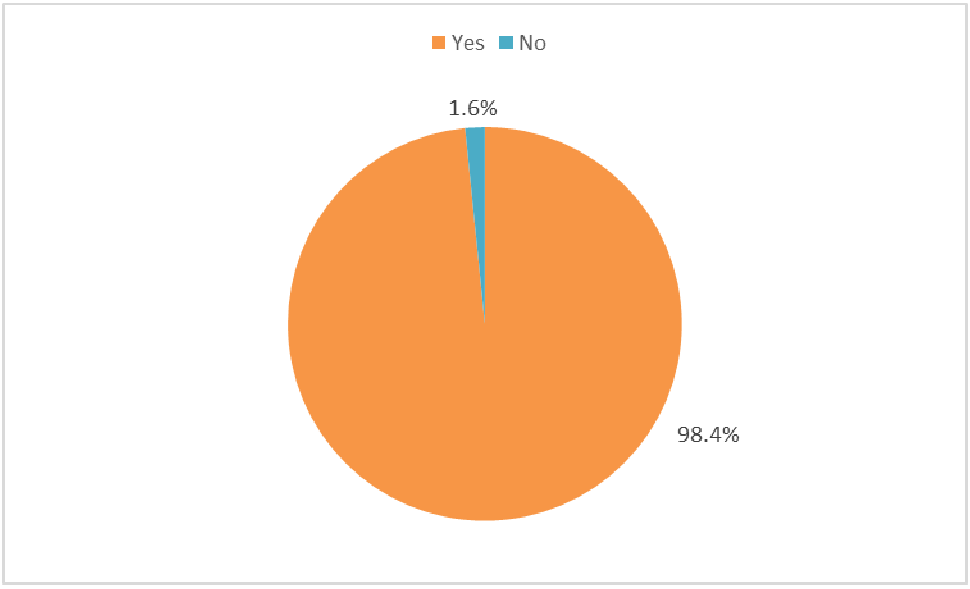

Figure 5. Willingness of local communities to pay for bourgou seeds.

4. Conclusion

Bourgou fields (*Echinochloa stagnina*) are water ecosystems that provided several services for Inner Niger Delta inhabitants in Mali. These services are fodder for cattle, fishing, and habitats for biodiversity (waterbirds, hippos, fish). The production of bourgou is practiced by fishers, herders, and farmers but its management is ensured by local authority called "djoro". Each producer of bourgou cultivate 7 ha annually. Bourgou culture generates costs related to the purchase of seeds and the mobilization of labor for transplanting. The cost of 100 ha of bourgou is estimated at USD 5,4646.03 (17,076,885 FCFA). This means a charge of 170,768.85 FCFA/ha. The regeneration of 1454 ha costs USD 794,553.31 (248,297,908 FCFA). Revenues per 1454 ha of bourgou culture are estimated at USD 2,247,422.69 (702,319,590 FCFA). The economic value of bourgou ecosystem services is USD/ha 999.22 (312,257 FCFA/ha). However, bourgou fields suffer degradation due to passage of animals and diminishing space for their cultivation – due to expansion of rice production and the conjugated effects of climate change and infrastructure decision that led to a diminishing of the flooded zone and water availability. To restore fields, 98.5% of producers agree to pay for its seeds for the regeneration of bourgou fields. It is necessary to elaborate and implement a policy for bourgou conservation and restoration taking account its several ecosystem services.

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