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1 Economic importance of fuelwood in family resources is not a
2 sufficient trigger factor for farmers to restore their parklands in
3 south-western Niger

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18

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24 this study.

25

26 **Abstract**

27 In Niger, literature from the years 1990-2020 shows a rapid regression in the surface areas of forest, an abundant
28 regeneration of trees in some cultivated areas, and a sharp increase in the consumption of wood energy in cities and the
29 countryside, with this wood increasingly coming from parklands. This study, carried out in 2015-2019 on the outskirts of
30 Niamey, aimed to assess the economic benefits for households of parkland fuelwood production and the ecological state of
31 the parklands. Surveys were carried out among 90 farmers to assess the contribution of fuelwood to their household
32 income. Semi-structured interviews with focus groups were conducted in 3 villages to determine farmers' strategies and
33 practices. The inventory of the trees in the parklands was carried out in 3 villages (5,000 ha per village).

34 Most rural households have an income diversification strategy to cope with the vagaries of agricultural production. Among
35 these revenues, the sale of fuelwood occupies on average a small place (4 to 10%). To explain their reduced use of Assisted
36 Natural Regeneration (ANR) for the restoration of parklands, farmers point to the difficulty in exploiting wood pruned from
37 their trees due to conflicts of use with livestock herders, taxes and fines from environmental services agencies.

38 Trees and shrubs in parklands have a low diversity (24 species) and low density (5-8 trees / ha). The low density
39 of young trees indicates that during the past decade, there have been fewer efforts to enrich parklands compared
40 to the 1980s, when ANR projects were first implemented. The 3 parklands studied are in the process of
41 becoming severely degraded because dead old trees are no longer replaced through ANR. The Economic
42 importance of fuelwood in family resources is not a sufficient trigger factor for farmers to restore their parklands
43 but could support village's interest for sustainable management of natural forests.

44 These results should serve to alert public authorities and aid organizations that research and development actions
45 must be launched to reverse this deterioration trend in parklands.

46 **Keywords:** Fuelwood, Biodiversity, Parklands, Sahel, *Faidherbia albida*, Farmer Managed Natural Regeneration

47 **Introduction**

48 Over the past forty years, the Sahel has suffered several droughts, notably in 1973-1974 and 1983-1984. In Niger,
49 this phenomenon, coupled with an increase in the population from 5,102,990 inhabitants in 1977 to 17,129,076 in
50 2012 (RGPH 2012) has led to a serious deterioration in forest cover (Data for the 5th census in 2022 are not yet
51 available). It was estimated that the surface area of forests in Niger will have shrunk from 1.94 Mha in 1990 to
52 1.08 Mha in 2020, a 44% decrease in 30 years (FAO 2020). Many rural communities are facing shortages of
53 fuelwood and service wood, as well as declining soil fertility (Pieri 1989). This depletion has forced farmers to
54 modify their farming practices by drastically reducing fallow periods, overexploiting wood resources and
55 accelerating the clearing of land for agriculture to meet the increasing demand generated by the growing
56 population.

57 According greater attention to Sahelian Agroforestry Systems (AFS), and in particular parklands (Pelissier 1980),
58 to sustainably meet the needs of rural communities has thus become a pressing challenge (Peltier 2019). Several
59 development projects and actions by nongovernmental organizations (NGOs) have been undertaken to restore
60 parkland using assisted natural regeneration (ANR) practices (Montagne 1996; Larwanou et al. 2010; Pasiecznik
61 and Reij 2020).

62 Parklands in dry Africa, especially those with *Faidherbia albida*, are well-known AFS (Peltier 1996). These
63 AFS are part of a pastoral system, as livestock graze under the parklands in the dry season (October to May,
64 when the *Faidherbia* trees bear their leaves and fruits), drop crop residues, graze on branches pruned by
65 pastoralists and on the pods of this legume and make their droppings. Although animal droppings are simply left
66 on the ground, the fact that animals congregate in the shade of trees during the hot hours leads to trampling by
67 the herd, which allows a significant portion of the droppings to be incorporated into the soil, where their nitrogen
68 is released. These AFS are also part of rainfed cropping systems. Rainfed crops (sorghum, millet, cotton, etc.)
69 are grown during the rainy season (June to September, when the *Faidherbia* trees lose their leaves), reducing
70 their shade. The crops benefit from fertilization by livestock dung and nitrogen enrichment by the fall of leaves
71 and twigs. Since planting trees in cropland and pasture land is very difficult (young trees need to be protected,
72 sometimes irrigated etc.) this is why farmers favour natural regeneration by ANR, without protection or
73 irrigation, simply "hold the axe" at the time of clearing so as not to cut down the young tree or its shoots, and
74 then prune it in the following years, to favour its growth in height. This technique was rebaptized under the
75 name, Farmer Managed Natural Regeneration (FMNR), in particular by Haglund et al. (2011). These efforts

76 have made it possible to preserve some wood resources, and even to ensure the greening of certain over-
77 exploited areas (Bagnian et al. 2013).

78 Until recently, assessments of global forest resources were mostly limited to forests *sensu stricto* (uncultivated
79 and with dense canopy cover), without considering trees and bushes on agricultural land. In a 2014 study, the
80 FAO roughly projected that "land with tree cover" (including cultivated) in Niger would represent 8 Mha in 2015,
81 compared to 4.15 Mha in 1990, meaning an increase of 48% of the surface area (no information on tree density
82 was noted). In 2013, Herrmann and Tappan show the vegetation impoverishment despite greening in Senegal. In
83 2020, Brandt et al. have mapped the crown of trees more than 3m² in size, in dry West-Africa, including Sahel, by
84 satellite imagery.

85 Few studies indicate the contribution of agroforestry trees to the rural economy, particularly in Niger. However,
86 master plans for the supply of domestic fuel in the towns of Maradi, Zinder and Niamey (SDACDMZ 2015;
87 SDACDN 2017) have shown that parklands account for a growing proportion of the production of fuelwood
88 marketed in Niger (Montagne 2018).

89 The production of fuelwood, for sale or self-consumption, is among the strategies developed by rural producers.
90 The trees and wooded areas that villagers can access in their territory create a standing value that can take
91 different forms: land reserves for exploitation and cultivation, timber and poles that can be sold according to a
92 flexible calendar, an energy resource that can be sold continuously, a forage resource that can be rented out or
93 exchanged for services (Griffon and Mallet 1999; Petheram et al. 2006).

94 The present research, carried out in 3 villages in 2015-2019, aims to: i) assess the importance of fuelwood
95 (particularly that harvested in parklands) in farmers' incomes; ii) measure the state of tree resources in parklands;
96 and iii) determine farmers' strategies and practices regarding the trees in their fields.

97 These data are then compared and discussed to verify the following hypothesis: "The importance of fuelwood in
98 farmers' incomes has led to a dynamic of restoration and management of tree resources in their parklands". The
99 results should make it possible to guide the actions of a future fuelwood management project in the Niamey
100 supply basin and to provide elements to support a modification of the law regulating the management of
101 agroforestry trees in Niger.

102 Only one research activity on AFS was carried out in the area under consideration during the period 2015-2019
103 and, at the request of the Ministry of Environment, it focused on the description of woody stands and their
104 production of wood energy (Boubacar 2021). It was planned that other trainees or PhD students would work on
105 soil fertility, cultivation practices and the production of non-wood forest products (fruits, nuts, etc.), but this was
106 not possible due to the rapidly deteriorating security situation in the area. The many other products and services
107 that these parklands provide to local communities, the ecological processes that lead to the mortality of adult
108 *Faidherbia*, or other social processes that could lead to reduced interest on the part of these communities in
109 restoring their parklands, will have to be studied when conditions and means allow it..

110 **Methods**

111 Study area

112 Three villages were selected in 3 different communes in the fuelwood supply basin of the city of Niamey. In each
113 village, socioeconomic surveys were conducted to understand how farms operated. An inventory of the parklands
114 was carried out to determine the structure and floristic composition of the tree stands and to situate the
115 phenomenon of natural regeneration of different species in the cultivated area. The villages chosen for the study
116 were Safa (commune of Koygolo), Kobi (Tondikandia) and Tientiergou (Say) (Fig. 1).

117 These choices were motivated by the fact that Safa was a site of the Gao-Dosso project which worked to
118 reconstitute parklands using ANR (Montagne 1996) in the 1980s. In Kobi, no project intervention has been
119 documented. In Tientiergou, a village association was created in 1991 for managing natural forests and marketing
120 fuelwood (Rives et al. 2012).

121 In the 3 study areas, crop and livestock farming are the main socio-economic activities. There is an increasing
122 rainfall gradient from Kobi to Tientiergou, but the impact of rainfall on tree vegetation is complicated by the
123 variety of soils in each village (Tab. 1).

124 Socioeconomic study of the share of fuelwood in farmers' incomes

125 Ninety comprehensive semi-structured interviews (Sibelet et al. 2013) were conducted with farm heads and other
126 farm members available. The sampling aimed to explore the diversity of farms in terms of size and principal
127 production activity. Three focus group discussions were conducted, one in each village.

128 The main variables studied are: activities practiced (crop and livestock productions, non-farming activities),
129 means of production (agricultural surface area, available paid and family labors, agricultural equipment),
130 technical-economic results (quantities produced and sold, selling prices, income from non-farming activities),
131 household size and the objectives set for establishing and managing their parklands, the origin and quantities of
132 wood collected and the quantity of wood sold (Gafsi and Mbétid-Bessane 2007). The total household income of
133 each farm and the contribution to this income of each crop and livestock production and non-farming activities
134 were assessed. “Household income” includes the value of the family consumption of resources generated on the
135 farm or collected from surrounding areas. This made it possible to obtain the percentage of the overall income
136 coming from fuelwood. Non-farming income in the region includes farm work wages, salaried activity outside
137 agriculture, trade, and income from the sale of fuelwood. “Fuelwood income” is equal to the quantity of wood
138 collected (sold and/or self-consumed) valued at the local market price of the wood. This quantity was determined
139 on the basis of the weekly consumption (in bundles) of each farm studied. In addition, the locations where
140 fuelwood is collected were recorded.

141 Inventory of trees in three parklands

142 Landsat 2016 digital satellite images covering each of the communes studied were used to estimate the total
143 surface area of the parklands. Given the resources available, the zones to be inventoried were delineated over an
144 area of about 5,000 ha per commune. Such a zone covered, for example, about one-sixth of the AFS area in the
145 commune of Koygolo (Fig. 2).

146 The inventory was carried out by a systematic one-degree tree inventory with a sampling rate of 1.5%, which
147 represents the ratio between the surface area of the sample and that of the selected zone (CIRAD 2015). The
148 survey design was developed using a mapping tool (ArcView GIS software) and shows plots arranged on a square
149 grid with 772 m between lines and 772 m between plots. Their pre-calculated geographical coordinates were
150 integrated into a GPS.

151 The circular sampling units cover one hectare (a circle with a radius of approximately 56.42 m). In each
152 commune, 75 plots were inventoried, for a total of 225 plots. On each plot, dendrometric data (species, trunk
153 diameter at chest height, tree crown diameter and trunk height) were collected for all individuals with a height
154 greater than or equal to 3 m.

155 To assess natural regeneration (NR), circular plots with a radius of 7 m (154 m²) and the same center as the
156 sampling units also were set up. All woody species less than 3 cm in diameter were systematically surveyed and
157 recorded at the level of the NR study plot. The data collected were managed and processed using an Excel
158 spreadsheet to calculate the parameters of interest.

159 **Results**

160 Origin and quantity of fuelwood harvested

161 The two sources of fuelwood mentioned by the greatest number of interviewees in the three villages are the shrub
162 and tree formations on the plateaus (forests) and parklands (Fig. 3).

163 In Tientiergou, fuelwood is mainly harvested in a forest stand located on the plateau that is managed by the
164 “Rural Wood Market” (the village association). In Safa and Kobi, parklands are the main source of fuelwood for
165 rural people through the pruning of agroforestry trees and the harvesting of dead trees (Tab. 2). The proportion of
166 species in the fuelwood was not studied.

167 By considering the average weight of a wood bundle (20 kg) and the number of inhabitants in the villages, the
168 average self-consumption of wood per person per day was calculated to be 0.35 kg in Safa, 0.48 kg in Kobi and
169 1.39 kg in Tientiergou. The respondents explain this great difference in consumption by the availability of the
170 resource (abundant in Tientiergou, very rare in Safa). Other causes could not be found.

171 Diversity of total household income and contribution of fuelwood

172 The composition of total household income reflects the strategy developed by farmers to limit the risks inherent
173 in agriculture by diversifying food and cash crops and seeking off-farm income (Tab. 3).

174 In Kobi and Safa, almost half of the farmers' income comes from agricultural production based on market
175 gardening. This is due to the favorable conditions for agricultural production: a shallow water table and the fertile
176 alluvial soils in the Dallol river valley, and commercial outlets (weekly markets in the surrounding area). In Kobi,
177 potatoes are produced, and in Safa, fresh vegetables (salad, cabbage, tomatoes...) and a legume, the cowpea
178 (*Vigna unguiculata*). These products are mainly sold to generate cash resources, part of which is used to buy
179 millet (*Pennisetum glaucum*), the staple cereal consumed by the local population and one which is rarely
180 produced in sufficient quantities to meet household needs.

181 In Tientiergou, non-farming activities contribute most to total family income. This is due to the proximity of
182 Niamey (salaried activities, trade ...) and the lack of potential for large-scale market gardening. Agricultural
183 income is dominated by livestock husbandry linked to the customs and knowledge of the majority of farmers
184 belonging to the Fulani ethnic group.

185 Tientiergou is the only site where fuelwood accounts for an important share of income due to the existence of a
186 forest stand on the plateau managed by the Rural Wood Market. In the other two villages, where wood mainly
187 comes from parklands and is mostly self-consumed, fuelwood for sale accounts for a much smaller share of
188 household income.

189 Farmers' strategies and practices regarding the trees in their fields

190 Due to strong government directives regarding tree protection, especially agroforestry, and regular reforestation
191 campaigns, farmers are wary when talking about tree management and censor their own words. The present study
192 was difficult to carry out because the principal investigator, the first author of this article, is an officer of the
193 Ministry of Environment, the agency responsible for both tree promotion efforts and punishing non-compliance
194 with regulations. During the first formal surveys, the majority of farmers adhered to the official line, saying that
195 they never cut or prune an agroforestry tree and they systematically conserve regeneration. In Safa, they recalled
196 the ANR efforts they had made when the Gao-Dosso project was being implemented; in Safi, they said that the
197 NGO SOS-Sahel also had encouraged them to practice ANR. However, this discourse was contradicted by the
198 facts of the inventories, which indicated a high rate of pruning and a low rate of ANR.

199 The actual situation was therefore gradually revealed through some slips of sentences, sometimes during the
200 semi-structured individual interviews once trust had been established between the interviewer and interviewee.

201 According to several farmers, the Ministry of Environment (commonly referred to under its former name, "Water
202 and Forests"), is impeding the rational management of trees. This is attested to by a farmer from Safa who states:
203 "What's the point of leaving and protecting trees that you can't even use as you please?" Another says: "The
204 agents apply the law too rigorously and it needs to be reviewed". One participant adds: "We are aware of the
205 importance of these trees in our fields. We don't want the trees to die or disappear, which is why we have left and
206 maintained them. But once the trees are grown, it is forbidden to do even a maintenance pruning, and if you do,
207 you are fined". Another point of discontent mentioned concerns the authorization granted by forestry officers to

208 timber operators to cut down dead trunks of *Faidherbia albida* trees in farmers' fields; according to farmers, these
209 operators pay a formal or informal fee to government agents without any monetary compensation to those who
210 cultivate or own the land). In another area altogether, several farmers also reported increasing mortality of mature
211 *Faidherbia albida* without being able to identify the cause.

212 With regard to pruning, numerous disputes between Fulani breeders and field owners were reported in Kobi. The
213 former sought to let their livestock forage on trees, particularly *F. albida*, and the latter sought to save their trees.

214 Evaluation of tree resources by inventory

215 Floristic composition of adult trees and regeneration

216 Twenty-four (24) woody species were present in the adult stand of the parklands in the three study sites and
217 twenty-one (21) species were inventoried with regard to regeneration.

218 Some tree species (*Celtis integrifolia*, *Detarium microcarpum*, *Diospyros mespiliformis*, *Prosopis africana*)
219 represented in large and medium diameters, but whose regeneration is not ensured in any village, are endangered;
220 this is all the more problematic for local communities as the species in question are multipurpose species.

221 Tree density in agroforestry areas

222 Densities are similar in the parklands inventoried in Kobi and Tientiergou (5.9 and 5.4 individuals/ha). In
223 contrast, density is higher in Safa (8.4 ind. /ha), particularly for *F. albida* (4.7 ind. /ha) (Tab. 4).

224 Stand population structure: distribution of trees according to size

225 The analysis of the diameter structure of trees and shrubs in the wooded parklands shows an asymmetric "bell-
226 shaped" distribution centered on class 2 (20-29 cm) in all of the study areas (Fig. 4).

227 Small (classes 1: $10 \text{ cm} \leq \text{diameter} < 20 \text{ cm}$) and large individuals (class 4 and above: $\text{diameter} \geq 40 \text{ cm}$) are little
228 represented in the stands.

229 Nevertheless, the inventories revealed a significant regeneration of trees less than 3 cm in diameter. In
230 Tientiergou and Safa, this natural regeneration has a density of about 2,000 trees/ha, compared to 500/ha in Kobi.

231 The density of regeneration of *Faidherbia albida* is sufficient to be able to carry out ANR in Safa and Kobi
232 (approximately 40 trees/ha), whereas this would be more difficult in Tientiergou (approximately 8 trees/ha).

233 **Discussion**

234 Contribution of fuelwood to farmers' household income

235 The income from fuelwood, although modest compared to other sources, is part of a diversification strategy that
236 is essential for the maintenance and future of farms. Agricultural activities, including animal husbandry, represent
237 on average 66% of total household income, compared to 34% for non-farming activities. These data are consistent
238 with those found in the literature. Indeed, in sub-Saharan Africa, non-agricultural sources of income generally
239 represent approximately 30 to 50% of household revenue (Reardon 1997). No doubt the proximity of the three
240 villages studied to the capital and the existence of a decent road network play a role in the importance of income
241 from non-agricultural activities. However, this study does not allow us to measure the importance of these factors.
242 The income from fuelwood is more important in Tientiergou (10% of average household income) than in Kobi
243 and Safa (2-3% of household income). This shows that when wood is available (e.g., proximity to a forest), it
244 makes a significant contribution to rural people's livelihoods. However, the simple calculation of the share of
245 fuelwood in farmers' income does not adequately reflect the social importance of fuelwood or characterize its
246 scarcity. In situations of scarcity, such as in Kobi and Safa, wood accounts for a very low share in household
247 incomes because other non-monetizable products (straw, leaves, twigs, manure, etc.) are used to replace the
248 missing wood. When this is not possible, households reduce the number of meals they cook (often only one
249 cooked meal per day in Safa, choice of dishes requiring little cooking, e.g. briefly boiled millet flour) and no
250 longer boil drinking water, which causes social, health and ecological problems (SDACDN 2017). Self-consumed
251 firewood is most commonly woman's work, and depending on the availability of fuelwood resources can take up
252 a large proportion of the daily time available. In addition, having to walk long distances to gather firewood
253 exposes women to sexual assault. Both of these factors make a regular supply of fuelwood on, or close to, the
254 farm more valuable than its financial value alone would suggest.

255 The results of this study reveal a paradoxical situation: restoring parkland through ANR is an action that would
256 benefit all of the actors on the territory in the long term; however, in the short term, individual interests prevail in
257 an economy of survival. In future studies, the issue of governance will need to be explored further, most certainly
258 in the light of Elinor Ostrom's work on common pool resource management. Local governance systems with a

259 collective discipline to manage agroforestry parklands have existed in the past and have been successful. It will be
260 necessary to study what has degraded them, and what can be done to restore them. By working on a larger scale at
261 the country level, it will be possible to better assess whether it is the projects, government and NGO actions and
262 subsidies that explain the higher density of *F. Albida* origin in some villages, as was found in only two villages
263 (Safa and Kobi) in the present study.

264 Floristic composition and density

265 *F. albida* is the most represented species in the agroforestry parks in Kobi and Safa, where it accounts for about
266 50% of the trees, and almost half of these trees have a diameter between 20 and 29 cm. In Safa, where the density
267 of *F. albida* is close to 5 trees/ha, it may be assumed that these trees were conserved during the Gao-Dosso ANR
268 support project, which was implemented between 1981 and 1985 (Montagne 1996). The project encouraged
269 farmers through a system of subsidies to protect the natural regeneration of *F. albida* where this was possible, and
270 helped them to plant seedlings where existing tree stands and soil conditions were not conducive to natural
271 regeneration. In Kobi, the efforts of the NGO SOS-Sahel also seem to have had some success (2.5
272 *Faidherbia*/ha). Such efforts were not made in Tientiergou (0.7 *Faidherbia*/ha).

273 Moreover, the toposequence around Safa and Kobi includes a dry valley (Dallol Bosso) characterized by a deep,
274 clay-loam soil, well supplied with groundwater or by temporary flooding. This explains the density of natural
275 regeneration of *F. albida* (about 40 indiv/ha in Safa and Kobi), much higher than in Tientiergou (8 indiv/ha)
276 where the soil is shallow above a lateritic breastplate or comes from the dementing of a lateritic breastplate. The
277 current composition of tree-covered parklands can therefore be explained, on the one hand, by the ecological
278 conditions favoring natural regeneration, and, on the other, by the willingness of farmers to assist this, often
279 supported in the past by extension projects.

280 Twenty-four species are present in the parklands on the three study areas, whereas at the level of young
281 regeneration, only 21 species were inventoried. Even though these data should be verified over larger areas, they
282 show that certain species which exist in large and medium diameters, but whose regeneration is not protected, are
283 tending to disappear. This suggests that a new effort to restore parklands through ANR could ensure the survival
284 of several, but not all, species. For the species for which there is no longer any regeneration, the survival of these
285 species could only be achieved through planting.

286 Stand population structure: distribution by tree diameter

287 Concerning *F. albida*, regeneration is weak but significant (40 individuals/ha in Safa and Kobi), while class 1 (10
288 to 19 cm) is very poorly represented. This this would suggest that farmers allow very few trees from natural
289 regeneration to grow to a diameter of 10 cm or more. On the basis of the available results concerning the average
290 diameter growth of *F. albida* (1.5 cm/year, according to Depommier and Detienne (1996)), one might think that
291 few regenerations have therefore been preserved over the past decade. But it is also possible that some farmers
292 would like to regenerate more *Faidherbia* but are unable to do so because of livestock damage or conflicts with
293 herders.

294 Whatever the cause, it can be seen a regression in the use of ANR compared to the very positive results that were
295 observed during the 2000s (Reij and Botoni 2009). In the villages studied, it should be noted that farmers are not
296 able to keep as many young trees as in the past. Concerning the increasing mortality of old *Faidherbia*, some
297 farmers mentioned the lowering of the water table and attacks by wood boring insects, these hypotheses could not
298 be verified. A team from the University of Maradi is working on the *Faidherbia* dieback (Toungiani et al. 2021).
299 The authors have, through inventories in the Dogondoutchi area and surveys of farmers, shown the mortality rate
300 of *F. albida* in agroforestry parklands and that this has an impact on agricultural production. However, the
301 scientific causes of this mortality phenomenon remain unclear.

302 Farmers' loss of interest in ANR

303 Although the restoration of wooded parklands is considered collectively useful, theories concerning the
304 management of common property (Ostrom 1992; Agrawal 2001) cannot be applied to explain individual
305 farmers' loss of interest in the restoration of these parklands. The decision to keep a young tree found among all
306 of the plants regenerating on a field, when clearing it prior to sowing, is a private decision made by the farmer.
307 Nor can economic theories on the management of private property like a "good parent" be applied. This is
308 because a significant part of the future benefits of a tree that is conserved, namely wood and aerial fodder, are not
309 at the farmer's free disposal, and may even be considered to be common goods given that the farmer must pay a
310 fee to the State to use them, and is fined if s/he does not comply with this legal obligation.

311 The appropriation by the State of the use of a good whose creation is based on a private initiative leads to the
312 disengagement of these private individuals and the progressive disappearance of the good. This holds true even

313 when there is no voluntary destruction of the good (the tree), simply by not compensating for the wear and tear of
314 time (in other words, by not replacing old trees which die).

315 To revive the restoration of *Faidherbia* parklands, the first step required would be to resume awarding subsidies to
316 those practicing ANR or planting (which would be a way to demonstrate public interest in these actions). At the
317 same time, or in a second step, the right to manage and harvest the trees that people have protected or acquired
318 should be ceded back to these individuals. However, local communities should maintain the right to arbitrate
319 possible conflicts, for example between livestock herders and farmers, as was mentioned, for other common
320 goods, by Ostrom (1990). We can also take into account the conclusions of Stith et al (2016) who consider that “it
321 is essential to take into account the relationships between development projects and local communities, kinship
322 and social networks, leadership across various spheres, and the resilience of indigenous environmental knowledge
323 in future analyses that explore the complicated suite of factors that have influenced the Sahel Regreening”
324 (Pasicznik & Reij 2020).

325 It should be noted that the first results of the present study were discussed during the National Colloquium on
326 "Management of forest resources in peri-urban territories and climate change", which was held from 31/10 to
327 2/11/2017 in Niamey (Boubacar et al. 2017). This most certainly contributed to alerting the government to the
328 ongoing degradation of agroforestry parks. Several members of this symposium contributed to the drafting of
329 Decree No. 2020-602/PRN/ME/SU/DD (République du Niger 2020). This decree states in particular the
330 following points: i) Article 4: Every field owner has the right to identify and maintain, plant and exploit the trees
331 of his choice in his field, and ii) Article 7: The owner has the exclusive right to exploit the green wood of the
332 agroforestry parks in his field. However, at the time of the study, the concrete effects of the application of this
333 decree could not be studied. Unfortunately, in March 2022, the text of decree n°2020-602, regulating the practice
334 of Assisted Natural Regeneration in Niger, has not been published either on the internet or on the websites of
335 government institutions. This decree has not yet been disseminated to those who are supposed to enforce the law
336 (the agents of the forestry brigades); its signature came at a time when a committee was set up to revise law 2004-
337 040 on the forest regime in Niger. The aim of this revision was precisely to take better account of agroforestry
338 parklands. So this decree alone cannot change the situation in the field without it being integrated into the law
339 itself because it is the basis for the work of the field agents.

340 **Conclusion**

341 Economic importance of fuelwood in family resources is not a sufficient trigger factor for farmers to restore their
342 parklands in south-western Niger, but could support village's interest for sustainable management of natural
343 forests.

344 Income diversification is crucial for most rural households in the Niamey region. Fuelwood plays a critical role
345 in this diversification when the resource remains abundant and is well managed, as is the case in Tientiergou
346 (10% of total income). On the other hand, in the villages of Kobi and Safa, where fuelwood comes essentially
347 from furtively pruning the few trees scattered across the parklands, fuelwood accounts for a low share of income
348 (less than 4%) and cannot cover all self-consumption needs. This generates shortages and forces the population
349 to use various plant residues that then can no longer serve to fertilize fields with organic matter.

350 The parklands studied have a low biodiversity (7 to 17 species per village), low density (5 to 8 individuals/ha),
351 scarce and often dying mature trees and few young trees (diameter less than 19 cm). This indicates that ANR,
352 which projects had promoted from 1980 to 2000, is being practiced by farmers less and less, and proves that these
353 parklands are no longer being restored. The mortality of old trees is in effect no longer being compensated by
354 ANR.

355 The findings of this work clearly show that one cannot continue to accept past, very optimistic reports that the
356 ANR is functioning perfectly in Niger and that the majority of parklands are in the process of regeneration.

357 On the contrary, it is clear that quite a few parklands are becoming severely degraded. To explain their loss of
358 motivation for ANR, farmers' groups pointed to conflicts between farmers, who once protected trees, and
359 livestock herders, who now come onto their fields to prune trees. Farmers feel that the pruning they do
360 themselves on their own trees is moderate and does not harm the trees' survival. Another explanation put
361 forward by several farmers concerns the formal and informal fines that environmental officials impose on
362 farmers who prune the trees in their own fields, even if they themselves or their relatives were the ones who
363 conserved them. They find this prohibition all the more unjust since the same officers allow outside loggers to
364 come and harvest timber from dead trees in their fields. The fact that wood has a significant economic value is
365 not enough to trigger action to protect young trees, because problems of formal or informal taxes, abusive
366 authorisations, and conflicts between farmers and herders, which make it impossible for the farmer to make a
367 linear link between increasing the number of trees in his fields and being able to harvest more wood in 20 years'
368 time, must also be addressed.

369 In the absence of a large-scale study, the work carried out on three villages does not, at this stage, make it
370 possible to offer definitive solutions for the entire country. However, it should make it possible to alert public
371 authorities and aid agencies of the need to launch research and development actions to reverse this trend, which
372 is threatening the survival of rural communities and some of the fuelwood supply chains serving the country's
373 capital. The research should focus on the social processes behind the population's diminished interest in
374 restoring parklands and on the causes of mortality of mature trees (climate change, overexploitation of water
375 tables, diseases, etc.). Legislative and development actions should focus, among other things, on regulating
376 negotiations between farmers and livestock herders, clarifying the law on agroforestry tree management and its
377 application, and on incentive mechanisms for farmers practicing ANR.

378

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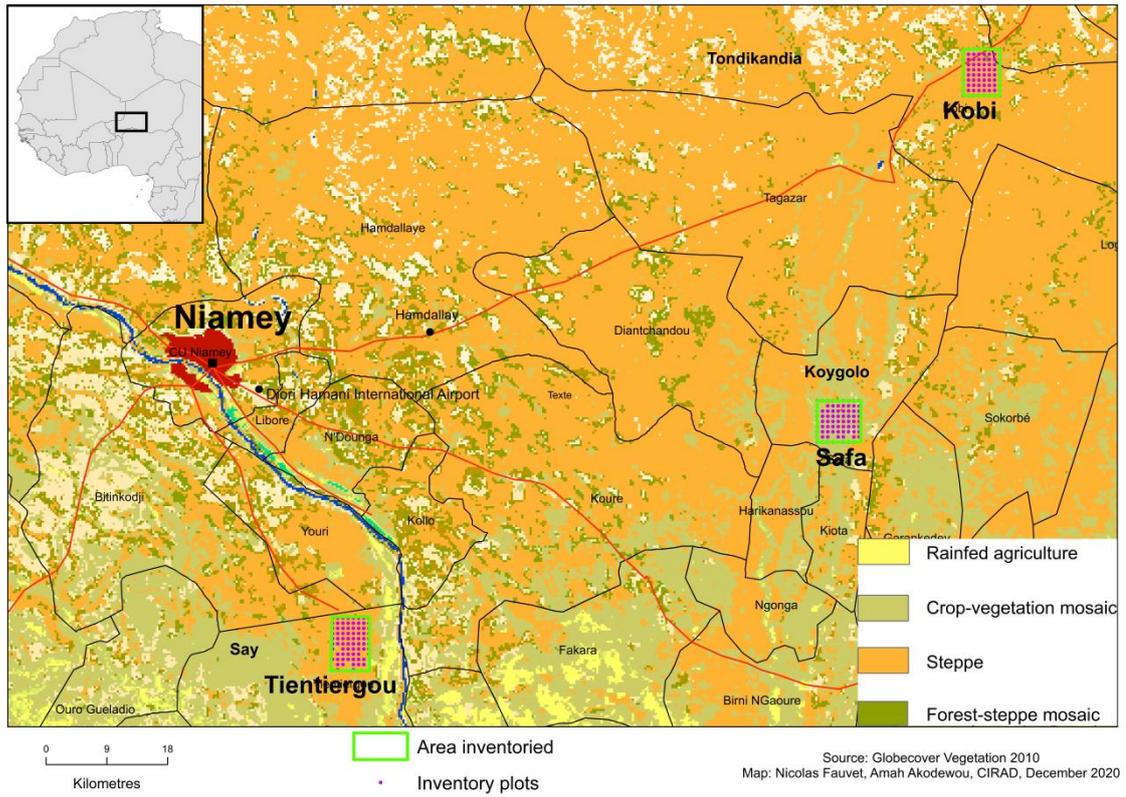
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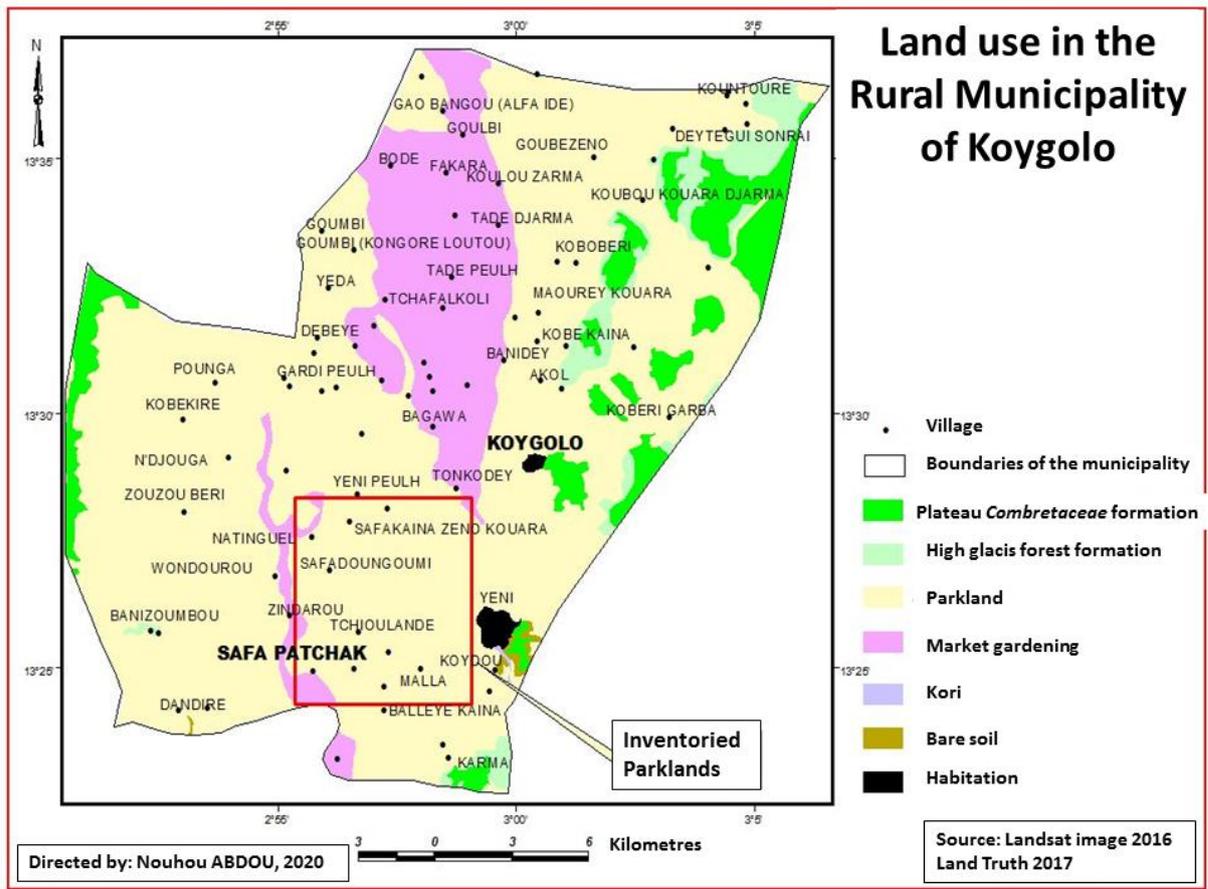
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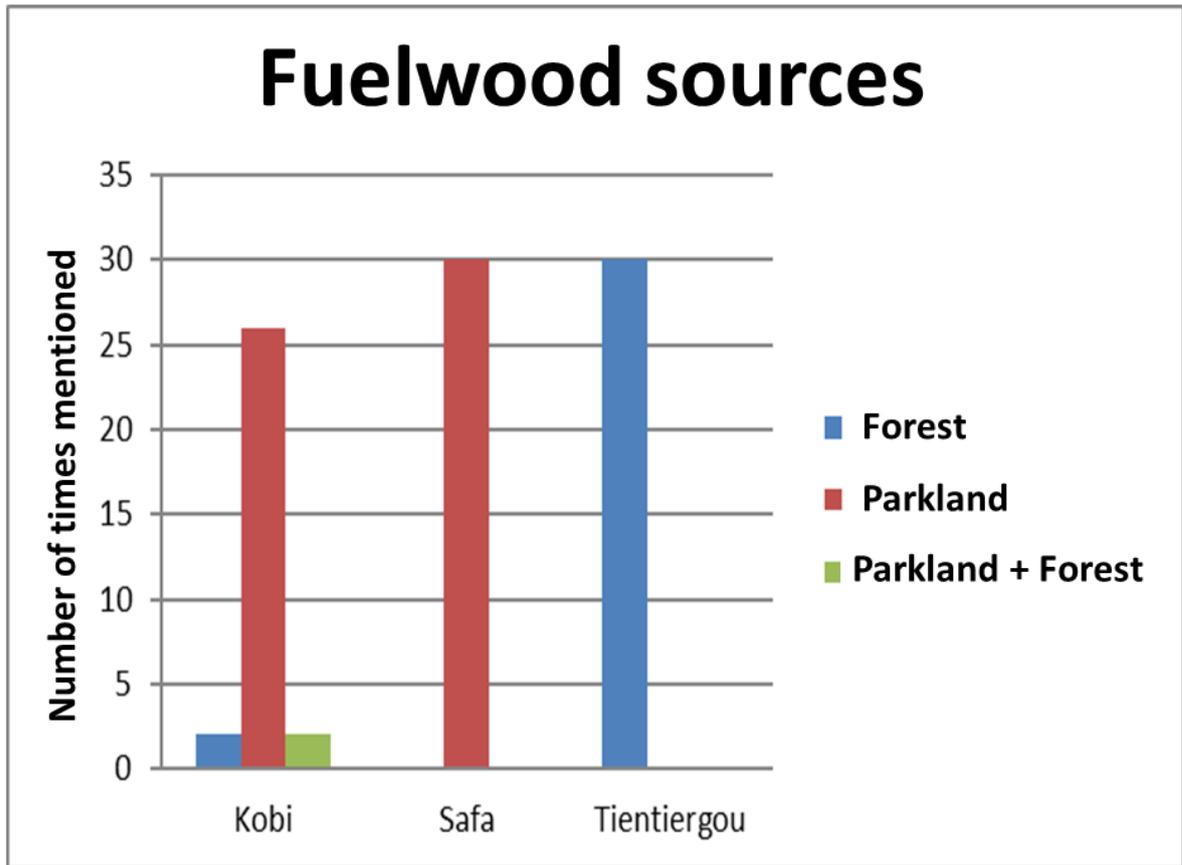
468 **Fig. 1:** Location of the study villages and the parklands inventoried

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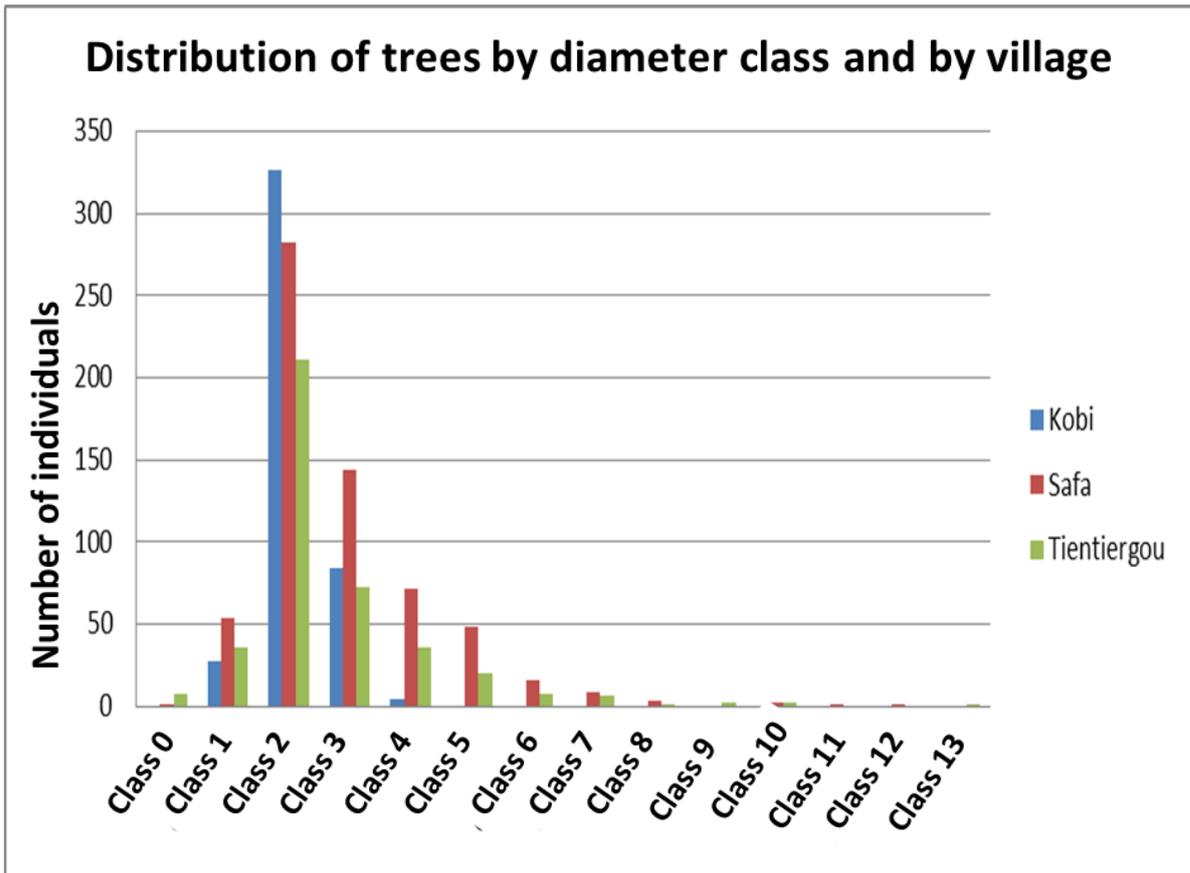
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471 Fig. 2: Boundaries of the parkland zones inventoried, village of Safa, commune of Koygolo



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473 **Fig. 3:** Origin of fuelwood mentioned in the three villages (n=90)



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475 **Fig. 4:** Number of woody species over 3 m high inventoried, by diameter class and by village

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Village	Climate	Geomorphological units	Vegetation
Safa	Sahelo -Sudanese with an average rainfall of 350 to 450 mm	Dallol Bosso (sandy fossil valley); Fakara overlooking Dallol valley.	<i>Faidherbia albida</i> , <i>Acacia nilotica</i> , <i>Balanites aegyptiaca</i> , <i>Parinari macrophylla</i> , <i>Sclerocarya birrea</i> , <i>Diospyros mespiliformis</i> , <i>Hyphaene thebaica</i> .
Kobi	Sahelian with an average rainfall of 300 to 400 mm	plateaus; Dallol Bosso and floodplains.	<i>Faidherbia albida</i> , <i>Balanites aegyptiaca</i> , <i>Ziziphus mauritiana</i> , <i>Guiera senegalensis</i> , <i>Boscia senegalensis</i> .
Tientiergou	Sahelo-Sudanese with an average rainfall of 450 to 600 mm	Niger River Valley; plateaus	<i>Balanites aegyptiaca</i> , <i>Boscia senegalensis</i> , <i>Acacia senegal</i> , <i>Guiera senegalensis</i> , <i>Piliostigma reticulatum</i> , <i>Bauhinia rufescens</i> , <i>Combretum micranthum</i> , <i>Combretum glutinosum</i> , <i>Faidherbia albida</i> , <i>Hyphaene thebaica</i> .

480 **Table 1:** Characteristics of the study areas¹

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¹ In the Dallol or the river valley, the roots of mature trees have access to groundwater; low rainfall consequently does not limit tree growth. In contrast, tree growth on the plateaus is dependent on rainfall. The vegetation found in the valleys and on plateaus, and the productivity of the wood resources, therefore differ.

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488 **Tab 2:**

489 Quantity (number of bundles per family per year) and destination of fuelwood harvested in each of the three
490 villages

Village	Kobi		Safa		Tientiergou	
Quantity (Number of bundles)	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
Harvested fuelwood	123.20	43.09	64.00	26.24	1149.98	1664.05
Self-consumed fuelwood	118.40	37.25	64.00	26.24	240.7	51.49
Fuelwood sold	4.80	26.29	0.00	0.00	909.28	1605.41

Villages	Kobi		Safa		Tientiergou	
Income	FCFA x 1000	%	FCFA x 1000	%	FCFA x 1000	%
Crop production	548.5	47.7	396.3	46.1	358.6	13.1
Animal productions	330.9	28.8	263.3	30.6	920.6	33.7
Non-farming activities	233.1	20.3	181.4	21.1	1 194.3	43.7
Tree resources (fuelwood) ²	37.0	3.2	19.2	2.2	260.8	9.5

491 **Tab. 3:** Contribution (in Francs CFA and in %) of the various activities to total household income in each of the
492 three villages (1000 FCFA = 1.8 USD)

² Fuelwood was valued at the average price (300 FCFA/Bundle) on the nearby markets in Kobi and Safa. In Tientiergou, the price varies between 200 FCFA per bundle on the informal market and 1250 FCFA per stere on the official rural wood market.

Strata	Safa		Kobi		Tientiergou	
	Adult stand	Regeneration	Adult stand	Regeneration	Adult stand	Regeneration
<i>Faidherbia albida</i>	4.7	42.5	2.5	39.9	0.7	7.8
<i>Balanites aegyptiaca</i>	1.7	-	1.2	133.5	1.1	42.5
<i>Hyphaene thebaica</i>	0.9	999.2	0.6	124.8	2.0	409.0
<i>Sclerocarya birrea</i>	-	-	0.5	-	-	-
<i>Combretum glutinosum</i>	-	-	-	-	1.0	-
<i>Annona senegalensis</i>	-	-	-	51.1	-	-
<i>Guiera senegalensis</i>	-	234.8	-	-	-	1659.5
<i>Bauhinia rufescens</i>	-	158.6	-	-	-	-
All species	8.4	1874.4	5.9	487.9	5.4	2145.7

493 **Tab. 4:** Density of dominant species (number of trees/ha) in wooded parklands by village