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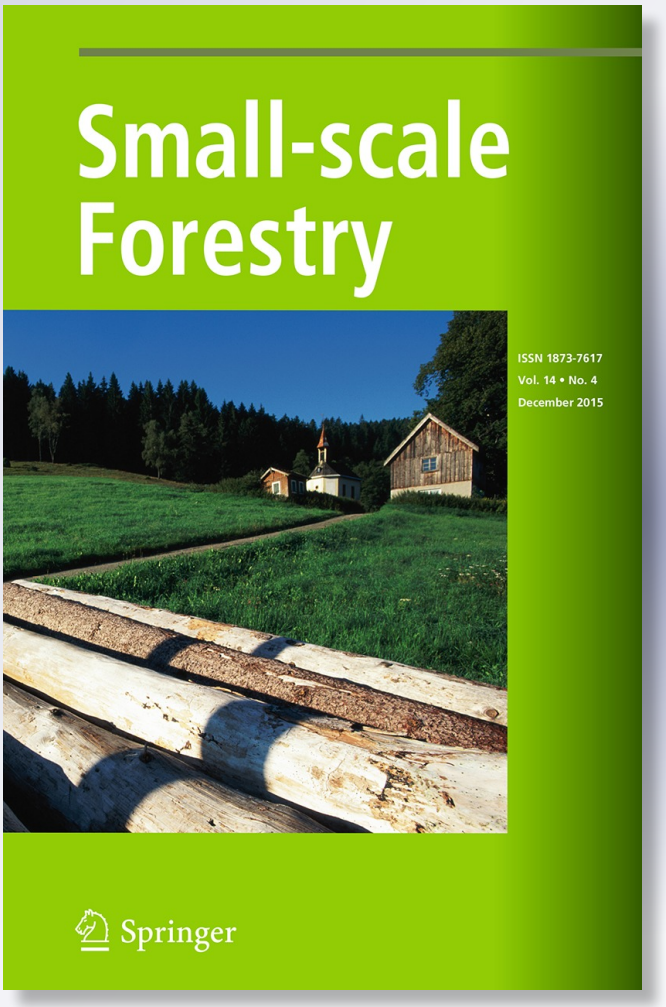

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RESEARCH PAPER

Unlocking Market Potential of Agroforestry Products Among Smallholder Farmers in the Sahelian and Sudanian Ecozone Countries of West Africa

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Abstract In the Sahelian countries, gathering of agroforestry tree products is one of the few livelihood activities that hold great potential for income generation and poverty reduction among resource-poor households. This study explores the determinants of market participation and selling decisions, which are key prerequisites for sustainable intensification and commercialization of the rural economy. A commercialized economy provides invaluable opportunities for smallholder farmers to increase their income and escape from poverty traps that are faced by most rural households in the Sahel. The results from a cross-sectional sample of 1080 households drawn from four Sahelian countries, namely Mali, Niger, Burkina Faso and Senegal, lend support to the relevance of three sets of variables in explaining agroforestry farmers' participation in markets and selling decisions. Market participation and selling decisions are affected by *predisposing*, *facilitating and reinforcing factors*. In areas where markets for tree products are functioning well, long distances from the main markets do not deter agroforestry farmers from participating in markets and selling decisions. This demonstrates that other interventions to strengthen value chains and market integration can be successful even where transportation is more costly.

Keywords Market participation · Sub-Saharan Africa · Predisposing factors · Facilitating factors · Reinforcing factors

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Introduction

Enhancing market participation by rural farmers is regarded as one of the most promising strategies for reducing poverty in developing economies where the majority of the rural population relies on agriculture for their livelihood. This is because improved access to markets has the potential to increase net returns to agricultural production (World Bank 2007). However, the majority of smallholders in Sub-Saharan Africa remain primarily subsistence farmers (Omiti et al. 2009; Siziba et al. 2013), with limited proportions of their production being sold to local markets. For instance, farmers in semi-arid areas of Africa are reported to market only small proportions of their output (Ellis 2005). Despite the low level of participation in agricultural output markets, there is overwhelming evidence that virtually all rural farmers depend on trading for some household needs and hence seek income generating activities (Siziba et al. 2013).

In the Sahelian countries, rural livelihoods depend to a large extent on a combination of rainfed crop farming and extensive livestock rearing, supplemented with the gathering of agroforestry tree products (AFTPs). These may be complemented with revenue generated by circular migration and remittances (Thea 2008). Harvesting of AFTPs is one of the few livelihood activities that hold great potential for income generation and poverty reduction, especially among resource-poor households, because of the widespread prevalence of valuable trees. Improved market access for the poor rural households is therefore a prerequisite for enhancing agriculture-based economic growth and increasing rural incomes.

Market development can be a tool for fostering rural development and reducing poverty. As described by Timmer (1988) and Staatz (1994), the typical agrarian transformation essentially involves farmers moving away from a subsistence production mode to a more market integrated mode. With increased market integration, farmers use more purchased inputs, produce more marketed surplus and have increased demand for other goods and services. This transformation process is self-reinforcing—as a household's disposable income increases, so does demand for variety in goods and services, inducing increased demand-side market participation, which further increases the demand for cash and thus supply-side market participation (Boughton et al. 2007).

Despite the well-known potential benefits of engaging in markets, very low levels of market participation are observed among smallholder farmers throughout most of Sub-Saharan Africa (SSA) (Coulter and Onumah 2002; Poulton et al. 2006; Barrett 2008). Stimulating market participation by smallholder farmers has been a policy challenge for many SSA governments beginning in the post-independence era. Efforts at enhancing market participation have seen policy swings from strong market interventionism to market liberalism associated with the structural adjustment programs (SAPs) of the 1980s. Barrett (2008) contended that the difficulty with improving market participation is that market participation is both a cause and consequence of economic development.

Research on smallholder participation in agricultural markets focuses on general issues such as whether farmers make market participation decisions and the volumes

of sales simultaneously or sequentially, institutional factors that affect market participation, and the effect of government policies on market-participation decisions. Goetz (1992), Heltberg and Tarp (2001), Lapar et al. (2003) studied market participation based on the assumption that market participation and volume choices are made sequentially. That is, farmers initially decide whether to participate in the market, and then decide on the volume sold, conditional on having chosen market participation. Another empirical study that has attempted to determine factors influencing market participation and intensities among agricultural enterprises is that of Omiti et al. (2009), which found that location of the farmers in rural areas and distance from the farm to the point of sale were major constraints to the intensity of market participation, while higher output price and better market information were key incentives for increased sales.

This study focuses on the determinants of participation and the intensity of participation in AFTPs markets in the Sahelian countries. In these countries, AFTPs play four main functions in the household economy of rural communities living in or adjacent to parkland. First, they help to fulfill household subsistence and consumption needs in terms of energy, nutrition, medicinal and construction needs. Second, they provide soil nutrients and fodder for crop and livestock production systems. Third, they serve as a safety net in times of crises such as income shortages and crop failure due to drought. Fourth, some AFTPs provide regular cash income through marketing (Maranz et al. 2004; Teklehaimanot 2004; Kalinganire et al. 2007).

Many authors in Sahelian countries provided a full description of priority functions of some major species found in Sahelian parklands (Diallo 2001; Maranz et al. 2004). However, there is a dearth of information on the drivers of market participation and selling decisions among smallholder agroforestry farmers in Sahelian countries. This study aims at bridging the aforementioned gap by examining factors affecting market participation and selling decisions of AFTPs in four Sahelian countries, namely Mali, Burkina Faso, Niger and Senegal. Improving access to markets to enable smallholder agroforestry farmers to benefit from the rapidly growing demand for some of the aforementioned AFTPs is one option that policy-makers need to consider. Therefore, the findings of this study will be useful for devising market-access policy prescriptions.

The paper proceeds as follows: a simple framework for investigating market participation and supply decisions is presented in the second section, followed by the presentation of empirical research methods in the third section. The results are presented and discussed in the fourth section, while in the fifth section, conclusions and policy implications are presented.

Theoretical Framework

Previous studies on market participation have typically adopted a two-step analytical approach involving the decision to participate and the intensity of participation in the markets (Winter-Nelson and Temu 2005; Alene et al. 2008; Mathenge et al. 2010). While most empirical studies on supply of output marketed

or input demanded have used Heckman's (1979) sample selection model or its variants of double hurdle and switching regression models (Winter-Nelson and Temu 2005), some use the more restrictive Tobit model to analyze supply of output marketed (Holloway et al. 2000). These procedures are discussed broadly in Maddala (1988) as well as Wooldridge (2002).

The Heckman two-stage model was deemed appropriate for this particular study owing to the limitations of standard regression models, including the ordinary Least Square method (OLS), which result in biased estimates when data are censored, or sample-selected (Breen 1996). Other regression models such as the logit and probit models, which are normally used to estimate limited dependent variables, are insufficient because they provide information on the determinants of the decision to participate but fail to make use of the quantitative data obtained from the households who decide to participate in selling AFTPs (Breen 1996; Long 1997). The Tobit model, on the other hand, which takes into account the non-zero values in the analysis, has a major limitation in that it assumes that the same set of parameters and variables determine both the probability of market participation and the intensity of participation (Long 1997). The two-step Heckman model relaxes the aforementioned assumptions by allowing different mechanisms to determine the discrete probability of participation and the intensity of participation.

The Heckman model assumes that some right hand side (RHS) variables may affect differently the decision to participate at all and the decision on the intensity of participation. The model assumes that the decisions to participate and the intensity of participation are made simultaneously (i.e. the error terms of the two equations are correlated). It is assumed that a value of zero on the sales variable represents the decision not to sell, hence no individual household is observed at the corner (zero) solution in the sales intensity decision. Therefore, the supply curve for output marketed is established only for the households that sell AFTPs and the members that do not sell do not influence the supply curve.

The first step of the Heckman procedure involves establishing the probability of participation in the AFTPs market by estimating a probit model. Assume that $s^*_{iaftp} = 1$ represents households that sell agroforestry tree products and $s^*_{iaftp} = 0$ otherwise, and s^*_{iaftp} denotes the unobserved desired propensity to sell. For the sample of n observations, there are m observations for which participation is positive $(s^* > 0)$, the rest of s and ε being truncated. The conditional expectation of s given $s^* > 0$ is as follows:

$$\begin{aligned} E\left(S_{aftp}|s^*_{aftp}\right) &= \xi + \beta X + E\left(\varepsilon|s^*_{aftp} > 0\right) \\ &= \xi + \beta X + E(\varepsilon|\varepsilon^* > -\xi - \beta X) \end{aligned} \tag{1}$$

ξ is the error term in the selection model and $\xi \sim \mathrm{N}(0, 1)$. Given that $\varepsilon^* \sim N(0, \sigma^2)$, the mean of the corresponding truncated variable, ε, is equal to:

$$E(\varepsilon|\varepsilon^* > -\xi - \beta X) = \sigma\lambda$$

where $\lambda = f\left(\frac{\xi+\beta X}{\sigma}\right)/F\left(\frac{\xi+\beta X}{\sigma}\right)$, and $f(\cdot)$ represents the density and $F(\cdot)$ the cumulative distribution function of a standard normal variable. To allow for nonzero

mean of ε, the regression equation for m observations for which $s^* > 0$ can be written as:

$$s = > -\xi + \beta X + \sigma\lambda + \varepsilon^* \tag{2}$$

The indicator λ is not observable, but it can be consistently estimated by forming a likelihood function for the binary variable in the probit model. As such, the first step (probit model) provides estimates of $(\xi + \beta X)/\sigma$ and thus λ.

Normally, the second step involves applying a linear regression using observations from which $s > 0$ in the regression model to be estimated. The linear regression (or Heckit) coefficient for λ will be statistically significant if sample selectivity bias occurs, while the remaining variables will be consistent (Heckman 1979; Goetz 1992; Winter-Nelson and Temu 2005). Following Maddala (1988), instead of using only the non-zero observations on S_{aftp}, using all the observations yields:

$$\begin{aligned} E(s_{aftp}) &= \Pr(s_{aftp} > 0) \cdot E(s_{aftp} | s_{aftp} > 0) + \Pr(s_{aftp} = 0) \cdot E(s_{aftp} | s_{aftp} = 0) \\ &= F(\cdot)_{aftp}[\xi + \beta X + \sigma\lambda] + \left[1 - F(\cdot)_{aftp}\right] \cdot 0 \\ &= F(\cdot)_{aftp}[\xi + \beta X] + \left[\sigma f(\cdot)_{aftp}\right] \end{aligned} \tag{3}$$

After obtaining estimates of $f(\cdot)_{aftp}$ and $\mathrm{F}(\cdot)_{aftp}$, Eq. (3) can be estimated using linear regression methods such as OLS. The threshold value in Eq. (3) is zero, thus applying a highly restrictive assumption. The components of Eqs. (2) and (3) consist of two terms making total effects of the whole sample. The first component is the direct effect of the covariates of those of households participating in the market, while the second is the selection effect captured through the inverse mills ratio.

Model Specification

The dependent variable, market participation, is measured by both the probability of selling and the value of agroforestry tree products sold in the market. Thus there are two dependent variables for each household. The first variable indicates whether the household participates in the market. This is an indicator variable, which takes the value of one if the household participates, and zero otherwise. For those who participate, the second variable indicates the value of output marketed, which constitutes the level of participation. To determine factors affecting participation and intensity of participation, a number of covariates are specified to reflect the potential effects of observed covariates and the transportation costs. The variables included in the two models as well as their expected signs are summarized in Table 1.

Factors that may influence a household's participation decision in AFTP marketing including the intensity of participation are classified into three constructs: *household structure*, *household endowment (access to assets)* and *access to information and markets*. All the variables discussed below enter the participation

Table 1 Description of variables used in the analysis

Variable	Unit	Participation model	Intensity model	Expected sign
Household structure				
Gender of the household head (1 = male, 0 = female)	%	Yes	Yes	–
Number of active members in the household (aged 15–64)	Number	Yes	Yes	
Dependency ratio[a]	%	Yes	Yes	+/−
Household endowments				
Production assets				
Size of arable land	Ha	Yes	Yes	+
Number of livestock unit owned (tropical livestock units-TLU)	Number	Yes	Yes	+
Number of young mature trees on farm (Diameter[c] between 40 and 60 cm)	Number	Yes	Yes	+
Number of old mature trees on farm (Diameter more than 60 cm)[b]	Number	Yes	Yes	−
Asset index		No	Yes	
Transport assets				
Household owns a cart (1 = yes, 0 = no)	%	Yes	Yes	+
Household owns a motorcycle/bicycle (1 = yes, 0 = no)	%	Yes	Yes	+
Information assets				
Household owns a TV (1 = yes, 0 = no)	%	Yes	Yes	+
Household owns cell phone (1 = yes, 0 = no)	%	Yes	Yes	+
The highest level of education within the household is primary (1 = yes, 0 = no)	%	Yes	Yes	+
The highest level of education within the household is secondary (1 = yes, 0 = no)	%	Yes	Yes	+
Institutional factors				
Average distance to the main market	Km	Yes	Yes	−
Number of interactions with extension agents	Number	Yes	Yes	+
Participation in other development projects (1 = yes, 0 = no)	%	Yes	Yes	+
New practitioner of natural regeneration[c] (1 = yes, 0 = no)	%	Yes	Yes	+/−
Always practitioner of natural regeneration (1 = yes, 0 = no)	%	Yes	Yes	+

[a] The dependency ratio is the ratio of the total number of household members aged 0–14 and 65 years and over to the total number of household members aged 15–64

[b] The values refer to diameter at breast height

[c] The classification of farmers into new and always practitioner of natural regeneration was based on land holding and or ownership, knowledge of the practice, and the age, number and diversity of trees kept and managed on the farm. New practitioners are farmers with a regeneration index greater than one while always practitioners are farmers with a regeneration index equal to one. Nyemeck et al. (2015) provide further details on the classification

and intensity model except two variables under household endowments– quantity of tree products and asset index—which are included in the intensity model only.

The *household structure* variables capture a number of possible concepts of household behaviour. In market participation these may reflect the attitudes of farmers towards risks caused by price and quantity fluctuations (Nkendah 2013). *Household structure* variables include gender, age and dependency ratio. Gender of household head is expected to capture differences in market orientation between males and females, with females expected to have higher propensity to participate in marketing of AFTPs than males (Mathenge et al. 2010). The size of productive labour force available in the household is proxied by the number of individuals aged between 15 and 64 years old. It is posited that a higher dependency ratio (a higher proportion of young children and elderly household members) will result in a household consuming a higher proportion of its harvest, thereby reducing the propensity to participate in marketing of AFTPs. However, because young children will comprise the bulk of the numerator in the dependency ratio it is also important to recognize that children supply labour for collection or harvesting as well as a high level of consumption of AFTPs (Alene et al. 2008). This may tend to increase the supply of marketed surplus for AFTPs.

Household Endowments

Access to assets provides households with the leverage to invest in productive activities, generate more output, and thereby increase their probability to participate in market transactions. Access to assets is an indication of endowment and wealth. A composite indicator, asset index, is used as a proxy for wealth such that the underlying indicators on which it is based reflect household's ownership (or lack thereof) of a range of assets. In this study, the range of assets that have been used as the basis for the construction of asset indices has been directly inspired by the set of durable household goods for which questions were asked in the survey (motorcycle, car, type of housing). However, the calculation of the indices has excluded assets including education level of the household head as suggested by Sahn and Stifel (2000), and the number of livestock owned by the household as suggested by Abreu (2012). The variables excluded from the composite index have been included in the model independently under production assets. Well-endowed households tend to experience lower transaction costs and have greater flexibility in allocation of resources to marketing activities (Azam et al. 2012; Siziba et al. 2013). Diversification of income sources reduces risks on the part of the households and may provide additional income for investment in agroforestry during lean periods. The total number of livestock units owned is used as a proxy for additional income available to the households.

Ownership of transport equipment such as cart, motorcycle or bicycle is expected to have a positive effect on participation and the intensity of participation by reducing the cost of transporting output to the market.

Access to information and markets tends to improve decision-making skills, which in turn affects the probability of market participation. Although information is neutral and therefore may increase or decrease incentives for a household to

behave in a particular way, it is hypothesized that because information on market opportunities is imperfect, greater access will generally help households to learn of additional opportunities for sale of products. The construct proxy representing access to information consists of contact with extension agents, basic average education, proximity to markets, ownership of television and cell phone, and membership in farmer groups proxied here as participation in development projects.

Extension agents are a valuable source of market information to farmers in addition to providing technical information on improved farming practices. As such, contact with extension agents is crucial for the farmers in making the decision to participate in the market. The contact, however, does not necessarily influence the intensity of participation. Market information reaching farmers requires proper interpretation.

In most cases, formal information is in French and those who cannot retrieve and interpret the information may have difficulties in making decisions including limited bargaining power. The highest level of education attained by household members is used as a proxy for the ability of the decision maker to retrieve and interpret information. The other variables relating to access to information and markets are location specific variables that are included to capture the role of travel costs in influencing market participation. The variable measuring proximity to the nearest market reflects how far farmers have to travel to reach the source of information. It is expected that longer distances increase travel time and travel costs, which impact negatively on market participation. Participation in farmer groups increases a household's awareness of the type of information needed for production and marketing decisions. Many farmer groups also engage in group marketing as well as credit provision to their members. Thus this variable is positively related to participation and intensity of participation in markets.

Research Method

Data used in this study were collected in 2012 from a survey of 1080 households and focus group discussions (FGDs) in four Sahelian countries, namely Burkina Faso, Mali, Niger and Senegal.

The study aimed to identify the effect of farmer-managed natural regeneration (FMNR) on household-level benefits and therefore areas where FMNR was not known to have occurred were excluded from the sampling delineation zone. Whereas the parkland system is ubiquitous in the four countries, recent evidence for regreening suggests that the phenomenon has been more widespread only in some locations. It is only within these zones that it was likely to be able to sample households practicing FMNR at differing levels.

Two stratification variables used in the sampling were rainfall and proximity to major markets (whether they are urban or rural trading centres). Within each country, relatively low and high rainfall belts were identified, generally distinguishing between areas below and above 600 mm of annual rainfall. Market access was measured by travel time where a 2-h level was used as a cutoff to distinguish better or worse access. Expert opinion was used to identify markets where many

agricultural products could be sold on a weekly basis as well as time taken to drive to these markets. Combining the climate and market variables produced four possible strata for site selection: (a) Drier climate, low market access; (b) Drier climate, high market access; (c) Less dry climate, low market access; and (d) Less dry climate, high market access. Within each of these four strata, 12 villages were selected at random so that 48 villages were included. Figure 1a–d shows the clustered locations of the households surveyed.

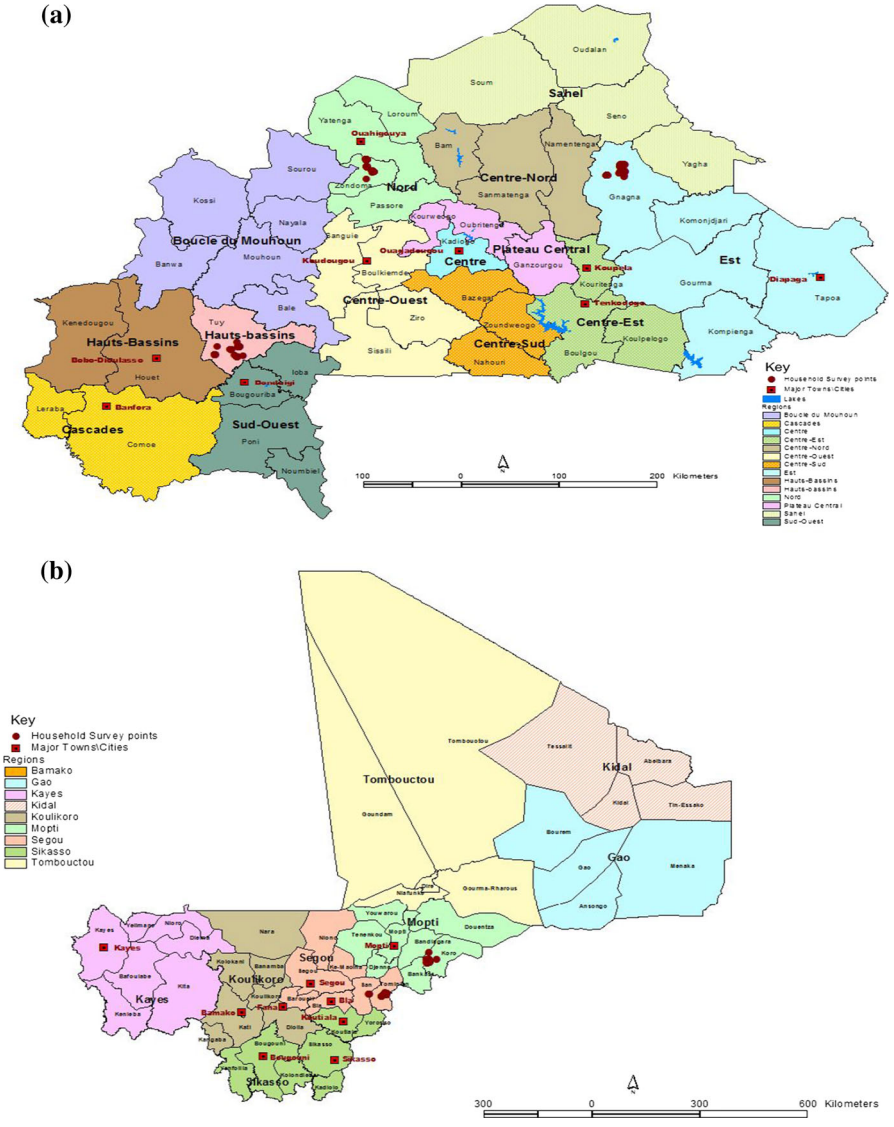

Fig. 1 Location of households surveyed in **a** Burkina Faso, **b** Mali, **c** Niger, and **d** Senegal

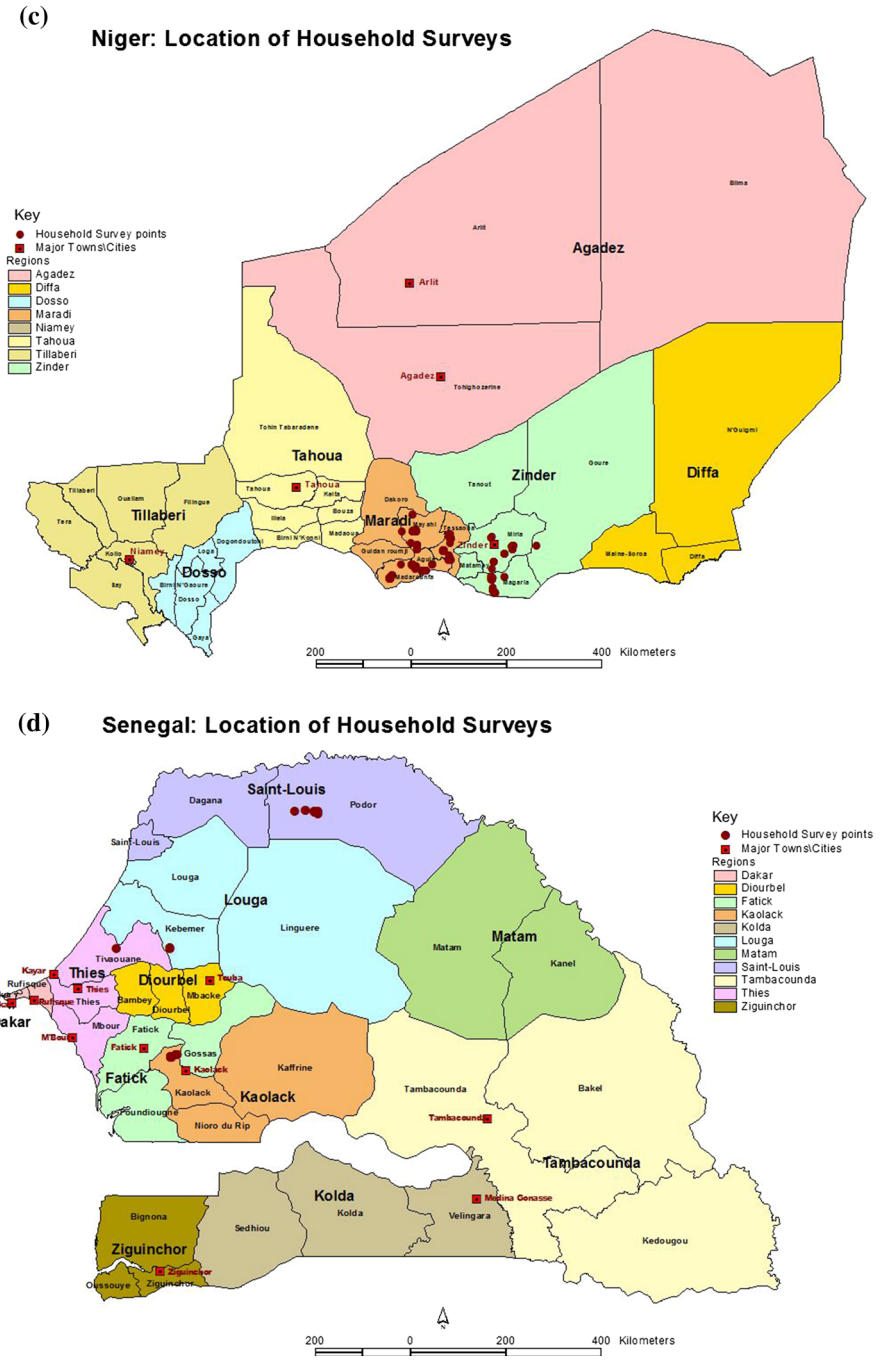

Fig. 1 continued

Within each village a two-step procedure was used to sample households. Through key informants, all households in a village were listed and identified as having a high or low density of trees on their farms (which proxies for adoption of FMNR). Then a random sample of 10 households in each stratum was selected giving sample sizes of 240 for Burkina Faso and Mali and 480 and 120 for the Republic of Niger and Senegal respectively. Convenience sampling was used to invite respondents into the FGDs, basing the selection on the respondents' knowledge and practice of agroforestry. Local extension agents and enumerators assisted to identify the appropriate individuals with sufficient knowledge of agroforestry.

The FGD questionnaire aimed to identify the major benefits from FMNR and how they are distributed across individuals, households and locations as well as to understand the main constraints in adopting FMNR. The household survey collected quantitative data about FMNR found on farm plots, including: tree species, number and age; sourcing of tree products (e.g. fruits and fuelwood) from farm and non-farm landscapes; all sales of tree products for the 2011–2012 agricultural year; crop and livestock production and sales; income from other activities; and characteristics of households and their land. Data on market values of tree products were also obtained from the household survey and complemented with additional market information on prices and unit measures.

Table 2 presents summary statistics of the variables used in the regression analysis. Notably, except in Mali, less than 50 % of households participate in AFTPs market as sellers. Most of the households were male-headed, with average family size varying from 8 to 16 individuals per household. The average number of active members in the households varied between 3 and 9 across the four countries. The majority of household members are dependents less than 15 years of age as indicated by the high dependency ratios. Between 38 % (Mali) to 67 % (Niger) of the households have at least one person with secondary level of education.

Crop production and livestock keeping are the main sources of income for most households in the four Sahelian countries. Sale of AFTPs, particularly fuelwood, fodder, leaves and fruit in various forms (fresh, dried and transformed into powder), is another important source of income for the households as indicated in Table 2. Sale of AFTPs—particularly from high-value trees including *Vitellaria paradoxa* (shea), *Parkia biglobosa* (nere), *Adansonia digitata* (baobab) and *Acacia* spp.—accounts for between 16 and 31 % of household income in the four countries.

Regression Results and Discussion

Tables 3 and 4 summarize results of the market participation and sale intensity models. Because the estimate for correlation between error terms in the participation and intensity regressions is not statistically significant, the market intensity model can be simplified to OLS for the case of Burkina Faso. The lower set of results in Table 4 shows the correlation coefficients between the unobservables of the participation and intensity regressions (ρ). The estimated selection coefficient lambda or the inverse mills ratio (IMR) is equal to sigma multiplied by rho. To

Table 2 Summary statistics of variables used in the analysis

Variable	Country			
	Burkina Faso (N = 240)	Mali (N = 240)	Rep. of Niger (N = 480)	Senegal (N = 120)
Dependent variables				
Probability of selling tree products	47.9	53.3	32.1	43.3
Value of tree products sold (in CFA francs)	30,000 (15,000)[a]	34,400 (10,000)	5520 (2500)	17,600 (9300)
Share of tree products to household's income (%)	29.42	21.59	31.2	16.10
Covariates				
Household structure				
Male headed households (%)	70.81	100	99.58	97.50
Number of active members in the household	3 (1.72)	9 (4.8)	4 (1.5)	6 (2.0)
Dependency ratio	0.55 (0.21)	0.48 (0.22)	0.60 (0.14)	0.53 (0.15)
Household size	8 (4.0)	16 (10.0)	12 (6.0)	12 (6.0)
Household endowment				
Production assets				
Size of arable land (ha)	5.96 (5.53)	9.09 (9.05)	2.17 (1.9)	8.3 (5.8)
Number of livestock unit owned	10.48 (12.10)	17.2 (22.6)	9.9 (5.01)	5.34 (5.05)
Number of young mature tree on the farmland	12 (15)	28 (27)	24 (52)	14 (17)
Number of older trees on the farmland	6 (8)	17 (23)	31 (83)	26 (26)
Transportation assets				
Household owns a cart (1 = yes)	29.2	92.1	43.5	64.2
Household owns a motorcycle/bicycle (1 = yes)	17.5	62.5	31.7	4.2
Information assets				
Household owns a TV (1 = yes)	56.7	18.3	1.5	27.5
Household owns a cell phone (1 = yes)	61.3	71.7	25.2	54.2

Table 2 continued

Variable	Country			
	Burkina Faso (N = 240)	Mali (N = 240)	Rep. of Niger (N = 480)	Senegal (N = 120)
Highest level of education within the household is primary (1 = yes)	84.5	74.5	10.04	79.2
Highest level of education within the household is secondary (1 = yes)	50	38.3	66.7	61.7
Institutional factors				
Average distance from the main markets (km)	20.07 (20.03)	5.3 (3.7)	7.4 (5.6)	7.1 (5.3)
Number of interaction with extension agents	2.11 (1.8)	0.85 (1.6)	0.33 (0.78)	0.33 (0.92)
If participating in other development projects (1 = yes)	61.7	20.0	22.7	21.7
If new practitioner of natural regeneration (1 = yes)	50.4	50.0	24.6	20.83
If always practitioner of natural regeneration (1 = yes)	25.8	29.2	44.08	26.7

[a] Numbers in parenthesis are SE

Table 3 Determinants of participation in agroforestry products' markets

Variable	Burkina Faso (N = 240)		Mali (N = 240)		Republic of Niger (N = 480)	
	Coefficient	Marginal effect	Coefficient	Marginal effects	Coefficient	Marginal effects
Constant	−0.750 (0.623)	–	−0.522 (0,504)	–	−2.061 (0.425)***	–
Household structure						
Gender of the household head (1 = male)	−0.54 (0.37)	−0.213 (0.139)	–	–	–	–
Number of active members in the household	−0.284 (0.208)	−0.113 (0.082)	−0.001 (0.131)	−0.003 (0.052)	0.001 (0.142)	0.001 (0.047)
Dependency ratio	1.09 (0.69)	0.434 (0.275)*	0.628 (0.589)	0.249 (0.234)	1.58 (0.624)**	0.525 (0.210)**
Household endowment						
Production assets						
Size of arable land	0.001 (0.134)	0.001 (0.057)	0.116 (0.104)	0.045 (0.041)	0.216 (0.103)**	.072 (0.034)**
Number of livestock unit owned	−0.003 (0.009)	−0.001 (0.003)	−0.001 (0.004)	−0.000 (0.001)	0.021 (0.009)**	0.007 (0.003)**
Number of young mature trees on the farmland	0.135 (0.106)	0.053 (0.042)	0.290 (0.101)***	0.115 (0.042)**	0.059 (0.072)	0.021 (0.024)
Number of older mature trees on the farmland	0.439 (0.115)***	0.171 (0.046)***	−0.409 (0.100)***	−0.162 (0.04)***	0.007 (0.069)	0.001 (0.023)
Transportation assets						
Household owns a cart	0.028 (0.29)	0.011 (0.119)	−0.057 (0.339)	−0.022 (0.134)	−0.041 (0.143)	−0.012 (0.048)
Household owns a motorcycle/bicycle	0.100 (0.300)	0.040 (0.119)	−0.086 (0.202)	−0.034 (0.080)	0.759 (0.155)***	0.272 (0.055)***
Information assets						
Household owns a TV	0.662 (0.28)***	0.257 (0.103)**	0.100 (0.234)	0.039 (0.093)	0.616 (0.458)	0.233 (0.194)
Household owns a cell phone	−0.295 (0.193)	−0.117 (0.076)	0.119 (0.215)	0.047 (0.085)	0.439 (0.188)**	0.137 (0.054)**
Highest level of education is primary	−0.100 (0.262)	−0.040 (0.104)	−0.205 (0.252)	−0.081 (0.100)	0.259 (0.697)	0.094 (0.264)
Highest level of education is secondary	0.100 (0.195)	0.040 (0.077)	0.495 (0.205)**	0.196 (0.086)**	−0.614 (0.152)***	−0.217 (0.064)***
Institutional factors						
Average distance from the main markets	−0.025 (0.008)***	−0.009 (0.003)***	0.041 (0.27)	0.016 (0.011)	0.045 (0.012)***	0.015 (0.004)***
Number of interaction with extension agents	−0.113 (0.054)**	−0.044 (0.021)**	0.094 (0.058)	0.037 (0.023)	0.277 (0.079)***	0.094 (0.026)***
Participation in other development projects	0.441 (0.261)*	.173 (0.101)*	−0.510 (0.247)	−0.020 (0.098)	0.401 (0.181)**	0.144 (0.067)**
New practitioner of natural regeneration	0.513 (0.246)**	0.198 (0.091)**	−0.132 (0.221)	−0.052 (0.088)	−0.209 (0.201)	−0.066 (0.063)

Table 3 continued

Variable	Burkina Faso (N = 240)		Mali (N = 240)		Republic of Niger (N = 480)	
	Coefficient	Marginal effect	Coefficient	Marginal effects	Coefficient	Marginal effects
Always practitioner of natural regeneration	0.554 (0.298)*	0.214 (0.112)**	−0.259 (0.250)	−0.102 (0.099)	0.129 (0.187)	0.047 (0.065)
χ^2	66.85***		27.54**		101.12***	
Pseudo R^2	0.22		0.08		0.23	
N	240		240		478	

Variable	Senegal (N = 120)		Sahel (N = 1080)	
	Coefficient	Marginal effects	Coefficient	Marginal effects
Constant	−1.044 (0.776)	–	−1.456 (0.308)***	–
Household structure				
Gender of the household head (1 = male)	0.345 (0.844)	0.128 (0.293)	−0.122 (0.177)	−0.047 (0.067)
Number of active members in the household	0.522 (0.338)	0.204 (0.131)	0.039 (0.078)	0.015 (0.030)
Dependency ratio	−1.294 (1.015)	−0.506 (0.395)	0.532 (0.307)*	0.208 (0.120)*
Household endowment				
Production assets				
Size of arable land	0.339 (0.328)	0.132 (0.128)	0.155 (0.051)***	0.060 (0.019)***
Number of livestock unit owned	−0.079 (0.029)**	−0.030 (0.011)**	0.002 (0.003)	0.001 (0.001)
Number of young mature trees on the farmland	0.284 (0.144)**	0.111 (0.056)**	0.135 (0.040)***	0.053 (0.015)***
Number of older mature trees on the farmland	−0.027 (0.152)	−0.010 (0.059)	−0.008 (0.037)	−0.003 (0.014)
Transportation assets				
Household owns a cart	0.038 (0.296)	0.015 (0.116)	−.004 (0.097)	−0.001 (0.037)
Household owns a motorcycle/bicycle	−.0311 (0.579)	−0.123 (0229)	0.190 (0.094)**	0.075 (0.037)**
Information assets				
Household owns a TV	−0.221 (0.320)	−0.087 (0.126)	0.297 (0.137)**	0.117 (0.054)**
Household owns a cell phone	0.044 (0.359)	0.017 (0.140)	0.192 (0.087)**	0.075 (0.034)**

Table 3 continued

Variable	Senegal (N = 120)		Sahel (N = 1080)	
	Coefficient	Marginal effects	Coefficient	Marginal effects
Highest level of education is primary	0.473 (0.378)	0.186 (0.147)	0.220 (0.104)**	0.086 (0.040)**
Highest level of education is secondary	−0.151 (0.329)	−0.059 (0.127)	−0.154 (0.086)*	−0.060 (0.033)*
Institutional factors				
Average distance from the main markets	0.062 (0.041)	0.024 (0.016)	−0.002 (0.003)	−0.001 (0.001)
Number of interaction with extension agents	−0.240 (0.124)*	−0.093 (0.048)*	−0.012 (0.031)	−0.004 (0.012)
Participation in other development projects	1.22 (0.423)***	0.402 (0.102)**	0.351 (0.101)***	0.138 (0.039)***
New practitioner of natural regeneration	−1.142 (0.378)***	−0.427 (0.130)***	−0.027 (0.105)	−0.025 (0.041)
Always practitioner of natural regeneration	−1.10 (0.414)**	−0.412 (0.145)**	−.081 (0.111)	−0.018 (0.043)
χ^2	41.78***		145.44***	
Pseudo R^2	0.24		0.10	
N	120		1080	

*** $P < 1$ %; ** $P < 5$ %; * $P < 10$ %

Table 4 Determinants of the intensity of marketing of agroforestry tree products

Variable	Burkina Faso (N = 240) Coefficient[a]	Mali (N = 240) Coefficient	Republic of Niger (N = 480) Coefficient	Sahel (N = 1080) Coefficient
Household structure				
Gender of the household head (1 = male)	0.022 (0.312)	–	−5.27 (0.413)***	0.99 (0.58)**
Number of active members	0.192 (0.167)	−0.067 (0.361)	0.024 (0.139)	0.057 (0.11)
Dependency ratio	−1.124 (0.557)**	−0.895 (1.321)	0.533 (0.596)	0.003 (0.48)
Household endowment				
Size of arable land	0.515 (0117)***	0.230 (0.123)*	0.296 (0.097)***	0. 263 (0.078)***
Number of livestock unit owned	0.002 (0.007)	−0.000 (0.008)	0.023 (0.008)**	0. 010 (0.005)**
Quantity of tree products harvested	0.094 (0.018)***	0.103 (0.023)***	0.026 (0.037)	0.081 (0.014)***
Asset index	−0.211 (0.143)	−0.149 (0.205)	−0.259 (0.136)**	−0. 242 (0.065)***
Number of young mature trees on the farmland	0.665 (0.321)**	−0.282 (0.201)	0.104 (0.068)	0.057 (0.060)
Number of older matured trees on the farmland	1.068 (0.333)***	0.566 (0.239)**	−0.050 (0.066)	0.093 (0.059)*
Household owns a motor bicycle/bicycle (1 = yes)	0.625 (1.211)	0.660 (0.508)	0.030 (0.161)	0.204 (0.107)**
Household owns a cart (1 = yes)	0.780 (1.161)	0.702 (0.640)	0.230 (0.155)	0.350 (0.136)**
Highest level of education is primary (1 = yes)	−0.674 (0.855)	−0.087 (0.568)	−0.436 (0.646)	0.684 (0.310)**
Highest level of education is secondary (1 = yes)	0.365 (0.584)	−0.653 (0.467)	0.694 (0.190)***	0.178 (0.139)
Household owns a TV (1 = yes)	1.45 (1.99)	0.307 (0.624)	−0.036 (0.550)	0.131 (0.219)
Household owns a cell phone (1 = yes)	−0.690 (0.569)	−0.179 (0.522)	0.435 (0.169)**	0.437 (0.140)***
Institutional factors				
Average distance from the main markets	0.023 (0.006)***	0.022 (0.062)	0.0442 (0.016)**	0.023 (0.007)***
Number of interaction with extension services	−0.417 (0.158)**	–	0.190 (0.100)**	0.308 (0.082)***
Participation in other development project (1 = yes)	1.972 (0.790)**	−0.378 (0.561)	0.117 (0.174)	0.056 (0.149)
New practitioner of FMNR (1 = yes)	0.820 (0.741)	0.230 (0.518)	0.250 (0.188)	0.002 (0.152)
Always practitioner of FMNR (1 = yes)	1.30 (0.890)	0.643 (0.608)	0.767 (0.185)***	0.570 (0.156)***

Table 4 continued

Variable	Burkina Faso (N = 240) Coefficient[a]	Mali (N = 240) Coefficient	Republic of Niger (N = 480) Coefficient	Sahel (N = 1080) Coefficient
Burkina dummy (1 = yes)	–	–	–	2.10 (0.622)***
Mali dummy (1 = yes)	–	–	–	1.80(0.324)***
Niger dummy (1 = yes)	–	–	–	–
Model performance				
Number of observations	240	240	480	960
Uncensored observations		228	240	815
Inverse mills ratio (lambda)		0.51	0.77**	0.682***
Rho		0.32**	0.53***	0.438***
Sigma		1.58	1.42	1.558
Wald χ^2		75.15***	105.25***	100.76***
F-statistic	8.12***			
Adjusted R^2	0.30			

[a] Model simplifies to OLS regression

*** $P < 1$ %; ** $P < 5$ %; * $P < 10$ %

judge the choice of modeling approach, it helps to evaluate the average selection effect computed as lambda multiplied by the value of average mills ratio. Their statistical significance in several of the models indicates that the use of the Heckman two-stage model avoided biased estimation coefficients which would have resulted if the two regression analyses were run independently.

The IMR indicates by how much the conditional value of marketed AFTPs is shifted up (or down) due to the selection effect. The interpretation of this is that a farmer with sample average characteristics in the Sahel who select (or is selected) into market participation secures (exp(0.117) − 1) 100 or 12.45 % higher tree products value than a randomly drawn individual from the population of farmers with a comparable set of characteristics would obtain. This is the case for the Sahel, Mali and Niger.

Consistent with expectations, households with a high number of young individuals (<15 years old) and therefore a higher dependency ratio are more likely to participate in the AFTP market. To meet both household requirements and market demand, a household intuitively needs to generate output in excess of its own consumption needs. Collection or harvesting of AFTPs such as leaves, fruits, pods is time consuming and labour intensive and in some places women and young children are the ones mainly involved in that activity. The positive sign implies that a household with a large number of young children provides cheap labour and collects or harvests more AFTPs in absolute terms such that the proportion available for market remains higher than the proportion consumed as observed by Alene et al. (2008). The results suggest that if the proportion of individuals less than 15 years old increases by 1 % the probability of participating in AFTPs market will increase by about 0.43 % in Burkina Faso, 0.53 % in Niger and 0.21 % in the Sahel as a whole.

The variable *access to land* has a significant marginal effect mostly in Niger where FMNR is mature and widespread, suggesting that access to more arable land might increase the probability of selling AFTPs significantly. In Niger, the practice of leaving and managing trees in crop fields known as FMNR is a standard farming practice. Typically, access to more arable land will encourage farmers to maintain and manage more valued trees, which leads to surplus produce requiring marketing. Similarly, the availability of more mature trees on the farmland yields more AFTPs, leading to marketable surplus.

The coefficients of the covariates representing the practice of FMNR are highly significant, suggesting that keeping, managing and planting trees on the farmlands increase opportunities for the diversification of income through marketing of AFTPs.

Being a female head of a household significantly increases the marketed AFTPs in Niger whereas its impact is negative and significant in the Sahel as a whole. Women in the Sahel are in the frontline in marketing many of the AFTPs including shea either processed or unprocessed. This is true for women in male- or female-headed households. A negative coefficient result may imply that in female-headed households, the head is occupied significantly more with growing crops, whereas in male headed households that responsibility is shared with the husband, freeing up more time for collection of AFTPs. The first type of AFTPs include those that are

processed and used as ingredients for meals, while the second include snacks or "fast food" from crude or fresh products that are generally eaten outside normal meal times and often when in the bush. Moreover, activities related to AFTPs, such as selling of shea nuts or extraction of shea butter by women, generate important incomes because they help communities overcome economic hardship during difficult periods, especially during and after natural calamities such as droughts (Kalinganire et al. 2007).

With the exception of ownership of transport equipment, most variables capturing access to information or markets, a proxy for transactions costs, have the expected signs and are in most cases significant in both the models. Thus, transportation costs constitute one of the major binding constraints to market participation and commercialization of AFTPs in the four countries. *Ownership of transport* equipment has a positive and significant influence on the probability of participating in markets for AFTPs. The coefficient estimates on the average distance to markets are highly significant but with differing effects across the four countries. For instance, distance to the nearest market is positively associated with participation in AFTP markets in Niger and the value of AFTPs sold in Burkina Faso, Mali and the Sahel as a whole.

The finding on the effect of distance on market participation and the intensity of participation is important because it suggests that in Burkina Faso and Mali where markets for high value tree products from *shea* and *Parkia biglobosa* are functioning well and the demand for the products is high, the long distance and low quality of roads might not be an obstacle for product commercialization. In this case the buyers usually travel to the rural areas to collect the products by themselves. The effect of distance to market on sales value is absent in Niger, probably because lower-value AFTPs such as fuelwood dominate sales there. Fuelwood can be sourced from a large number of tree species which can be found almost anywhere in the landscape. In practice, there is a cost savings incentive to source fuelwood nearer to major cities, but on the other hand, most supplies will be located further from cities.

The level of human capital in the household is positively related to AFTP market participation and sales amounts. However, this stock level appears to have an inverse relationship with participation and sales amounts when other employment opportunities requiring skills arise. In this way, a greater degree of intellectual capital—measured in terms of attainment of high school secondary level by the household head and any other member of the household—has a negative and significant effect on market participation in Niger. Thus, the propensity to participate declines among households with members having completed their post-secondary education in Niger, but this does not affect the amount of AFTPs sold; indeed, the relatively few educated households in Niger that do sell tree products, market higher values of AFTPs than others. The coefficient of asset index suggests that wealthier farmers are less likely to be involved in the selling of AFTPs, indicating that the activity could be a preserve of poorer households.

Exposure to development projects positively and significantly increases the likelihood of both participation and intensity of selling of AFTPs. Development projects are to some extent pathways for rural transformation because they facilitate

linkages between producers and buyers of AFTPs. A number of actions are often undertaken within the projects being implemented; including improved access to research, strengthening capacity of community based organizations and their interaction as well as networking with other stakeholders or actors along the AFTPs value chains.

Interaction with extension agents has significant marginal effects on the probability of selling AFTPs. This calls for the increasing involvement of advisory services in agroforestry. This is not often the case in many Sahelian countries where the management of AFTPs is generally guided and regulated by forest officers. In most cases where there are restrictive forest codes enforced by forest officers, the interaction between agroforestry farmers and the providers of tree management advisory services ranges from ambivalence to tolerance to outright disdain. Consequently, state institutions, when they intervene at all in the management of AFTPs, are regarded as ineffective by local people (Gratz 2007; Leach et al. 2011). This may explain the significant and negative effects of extension on both the probability of selling AFTPs and the intensity of participation observed in Burkina Faso.

Concluding Comments and Policy Implications

This study examined the determinants of market participation and selling decisions of agroforestry tree products, which are important for diversification, income generation and growth of the rural economy in the Sahel. The results lend support to the relevance of three sets of variables in explaining agroforestry farmers' participation in markets and selling decisions. The three sets of variables include *predisposing factors* related to the attributes of the household such as the proportion of household members younger than fifteen years, the size of arable land, the number of mature trees located on the household's farmland and wealth status; *facilitating factors* related to transportation and communication assets such as ownership of a cart, a motorcycle, a bicycle, a TV or a radio as well as the level of education; *re-enforcing factors* related to institutions and infrastructure including, distance to the main markets, exposure to development projects, interaction with extension services as well as the practice of FMNR. In general, households with a high number of young children, those having more arable land, many mature trees, transportation equipment such as a cart, a motorcycle or a bicycle as well as communication facilities such as TV or radio have a higher market orientation in tree products.

Contrary to the general belief that once infrastructure has been put in place then value chain actors will be motivated to engage in agribusiness, the results suggest that in areas where marketing of tree products is functioning well because of linkages with other value chain actors, long distances from the main markets do not deter agroforestry farmers from participating in markets and selling large quantities of tree products. On the other hand, if marketing of agroforestry tree products is poorly organized, the findings confirm the assertion in the literature that distance indeed constrains farmers from bringing substantial proportions of their products to

commercial markets. This study, therefore, suggests that simultaneous efforts to improve market integration, through investment in infrastructure, institutional reforms and building sustainable and predictable linkages to more lucrative markets are required for developing sustainable value chains.

Although further research is needed to corroborate some of these recommendations, there is anecdotal evidence to suggest that (1) providing support to producer groups dealing with AFTPs in the Sahel on improved management and harvesting techniques, (2) developing mechanisms through which value chain actors can easily access market information such as facilitating linkages and interactions through multiple stakeholder platforms and (3) strengthening the capacities of marginalized groups involved in marketing of AFTPs could be some of the strategies for alleviating agroforestry farmers' developmental constraints.

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