

Assessing Local Knowledge Use in Agroforestry Management with Cognitive Maps

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Abstract Small-holder farmers often develop adaptable agroforestry management techniques to improve and diversify crop production. In the cocoa growing region of Ghana, local knowledge on such farm management holds a noteworthy role in the overall farm development. The documentation and analysis of such knowledge use in cocoa agroforests may afford an applicable framework to determine mechanisms driving farmer preference and indicators in farm management. This study employed 12 in-depth farmer interviews regarding variables in farm management as a unit of analysis and utilized cognitive mapping as a qualitative method of analysis. Our objectives were (1) to illustrate and describe agroforestry management variables and associated farm practices, (2) to determine the scope of decision making of individual farmers, and (3) to investigate the suitability of cognitive mapping as a tool for assessing local knowledge use. Results from the cognitive maps revealed an average of 16 ± 3 variables and 19 ± 3 links between management variables in the farmer cognitive maps. Farmer use of advantageous ecological processes was highly central to farm management (48% of all variables), particularly manipulation of organic matter, shade and food crop establishment, and maintenance of a tree

stratum as the most common, highly linked variables. Over 85% of variables included bidirectional arrows, interpreted as farm management practices dominated by controllable factors, insofar as farmers indicated an ability to alter most farm characteristics. Local knowledge use on cocoa production revealed detailed indicators for site evaluation, thus affecting farm preparation and management. Our findings suggest that amid multisourced information under conditions of uncertainty, strategies for adaptable agroforestry management should integrate existing and localized management frameworks and that cognitive mapping provides a tool-based approach to advance such a management support system.

Keywords Cocoa production · Ghana · Farm management · Shade trees · *Theobroma cacao* · Agroforestry · Cognitive mapping · Local knowledge

As current policy and research on agricultural sustainability and resilience departs from a top-down approach, the inclusion of local knowledge has entered into the development paradigm; local knowledge is recurrently identified as an important component in sustainable farm development (Meehan 1980; Oudwater and Martin 2003; Rist and Dahdouh-Guebas 2006). The promotion of viewpoints that cross knowledge boundaries may provide a suitable approach to management, principally the inclusion of stakeholder perception of management practices (Hjortsø and others 2005; German and others 2006). Particularly in agriculture, the links between local farming knowledge and applied farm practices may advance management recommendations (Raedeke and Rikoon 1997; Bandeira and others 2002).

Cocoa (*Theobroma cacao* L.), a tree crop of high economic importance, is commonly found in small-scale

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production with understory food crops and upper-canopy trees (Duguma and others 2001). Multistrata planting schemes integrating crop, cocoa, and tree layers are purposefully developed by some farmers to increase farm products and minimize risk through diversification, supplement income, secure land tenure, and provide shade for cocoa plants (Sanatana and Cabala-Rosand 1982; International Cocoa Organization 1997; Beer and others 1998; Duguma and others 2001). Specifically, in regions with low access to or desire to use inorganic fertilizers, multistrata plantations are established and managed to maintain soil fertility and subsequently increase nutrient availability for cocoa through processes such as efficient nutrient cycling and increased biomass additions (Schroth and others 2001; Isaac and others 2007b). Certain upper-story canopy trees are retained (*Terminalia superba*, *Newbouldia laevis*, and *Ceiba pentandra*) and fruit trees, such as orange (*Citrus sinensis*), avocado (*Persea americana*), and mango (*Mangifera indica*), may be planted for shade, food, and other functions (Amoah 1995; Duguma and others 2001; Isaac and others 2005). However, the use of local knowledge in determining the preference for including trees and crops, and the process of such decision making, remains uncertain.

Conflicting results have been documented on the advantages or disadvantages of trees in the agricultural landscape, particularly the effects on productivity and fertility in cocoa agroforestry systems (Beer and others 1998; Schroth and others 2001; Hartemink 2005). Farmer response to such inconsistency often includes a variety of techniques adapted to the local conditions and frequently relies on local information and management decision making under conditions of uncertainty (Schulz and others 1994; Spender 1998). Such information on the integration of trees and crops within a cocoa plantation is accessed through both formal and informal sources, the latter being of particular importance to remote farmers (Kiptot and others 2006). In contrast to a previously assumed scenario of the farmer as a recipient of information, local farming knowledge, particularly in adaptive agricultural systems, is created within the community (Raedeke and Rikoon 1997). The current literature points to accessible informal information (Conley and Urdy 2001; Davidson-Hunt 2006; Kiptot and others 2006), particularly local knowledge regarding the most favorable species selection, planting densities, and cropping schedules for cocoa agroforestry systems (Isaac and others 2007a).

The Utility of Cognitive Mapping for Local Knowledge Analysis

To date, local knowledge research is typified by description and correlation of terminologies between scientific and

tradition paradigms (Hecht 1990; Braimoh 2002). In the current discourse on local knowledge, more work is required on the dynamic use of knowledge in order to provide information with management applications (Oudwater and Martin 2003). In combination with attributes to local knowledge, this study explored the process-oriented nature of farmer decision making and management of on-farm practices in a local context by employing cognitive mapping.

A cognitive map is a graphical representation of the structure of knowledge, providing a grounded method to organize and analyze complex ideas and concept relationships. Generally, a grounded theory approach utilizes an iterative process of coding or labeling emergent variables from interviews and depicts their interrelationships (Bernard 2002). Cognitive map analysis allows for such an approach and, particular to this study, allows for dominant features of the management process to emerge (Eden 1992; Farsides 2003). By depicting actual concepts in the process of farmer decision making, a network of connected arrows is created to represent relationships between concepts (Mendoza and Prabhu 2005). Using a cognitive map captures this thinking process and subsequent management actions, portraying the complex relationships of ideas (Ozesmi and Ozesmi 2004), and answering questions on, for instance, mechanisms of change and triggering events in the decision-making process (Eden and others 1992). Additionally, the use of this technique may afford some predictive qualities (Swan and Newell 1994), particularly on the use of localized knowledge. By mapping central factors in the use of local knowledge when undertaking farm establishment, cognitive mapping allows for the construction of motives and activities driving farm development. Note that cognitive maps focus primarily on explicit rather than tacit knowledge, as those participating frequently describe steps in management that are clearly explainable (Spender 1998).

Some work employing cognitive maps has focused on natural resource management topics (Hjortsø and others 2005; Robson and Kant 2007) and local knowledge systems in particular (Özesmi and Özesmi 2003, 2004), where more often than not a comparison is conducted between multistakeholders on a particular issue. The literature is scarce on cognitive mapping within an agricultural framework, the application to farm management, or determining similarities among decision makers. And as complex agriculture systems remain a prominent solution to food security as well as crop productivity and diversity, a tools-based approach to developing farm management support systems is essential.

To allow for documentation of dynamic knowledge use, we selected management steps in cocoa farm establishment and maintenance as the unit of analysis for this study. We employed cognitive mapping software to analyze results from in-depth interviews with farmers engaged in cocoa agroforestry. Our objectives were (1) to illustrate and

describe agroforestry management variables and associated farm practices, (2) to determine the scope of decision making of individual farmers, and (3) to investigate the suitability of cognitive mapping as a tool for assessing local knowledge use. The documentation and analysis of such farmer decision models will presumably offer insights into the use and limitations of local knowledge and management, while concurrently providing a current approach to developing appropriate strategies for process-oriented problem solving and decision making (Spender 1998) in an agricultural context.

Methods

Study Area

This study was conducted in Sefwi Wiawso District in the moist semideciduous tropical zone, Western Region (06°12'N, 02°29'W), Ghana, West Africa. Soils in the region are dominated by ochrosol-oxisol intergrades (Rhodic Ferralsol) (Soils Survey Division 1969). Mean annual precipitation is 1400 mm in bimodal rainy seasons (April to July and September to November), with an average above-ground temperature of 26.0°C. Cocoa has been recorded in Sefwi Wiawso District since the 1910s, and after fluctuations in price and success, by the 1970s cocoa was the principal economic crop and livelihood source in the region. Today, the two major economic activities that dominate the region are agriculture and forestry. Over 80% of the Sefwi population is involved in agriculture (Boni 2005). Although cocoa is a main cash crop in the region, other crops are cultivated either concurrently with cocoa or separately, including maize, cassava, plantain, cocoyam, rice, and yam. However, recent pressure for higher production has led to the removal of upper-canopy shade trees and understory food crop species (Boni and others 2004).

Data Collection: Interviewee Selection and Interview Structure

Participants were selected based on previous social network studies within these farming communities (Isaac and others 2007a). Social network analysis was conducted on knowledge transfer data collected from four socially separate but similar agrarian communities. This analysis identified a clear advice-seeking structure on farming information and specific core members within each community: core members were those who were highly sought for advice on agroforestry practices. For this study, semistructured in-depth interviews were conducted with a subset of core farmers ($n = 12$). For the purposes of this study, 'farmers' are any adults who currently have at least one cocoa farm

under their management, irrespective of tenure. Participants, all cocoa farmers for a minimum of 5 years, ranged in age from 28 to 75 years old and were from three separate but similar communities in the Sefwi Wiawso District of the Western Region, Ghana. All interviews were conducted in Sefwi, the local dialect, with an interpreter, and the same interpreter was used for all interviews during the study. Each individual interview was approximately 2 h in length, recorded on tape, and transcribed.

Grounded qualitative data analysis was achieved by employing cognitive mapping. Interview information was used to formulate maps for each individual farmer on the variables at play in the decision-making process for farm establishment and maintenance. Based on informal discussions with farmers, pre-established initial and end points of individual cognitive maps were set: clearing land for a new farm and the general central goal of financial gain. Therefore, the starting point for each map was classified as 'clear land' (as all farmers used this as a farm initiation point), with subsequent complexity of the nature of clearing land captured in greater detail in proceeding variables for each individual farmer. The end-point variable for each map was either 'productive cocoa' or 'less productive cocoa,' again as these were identified as the two outcomes of economic interest when managing a cocoa farm. These nodes were included in the recording of variable and connection numbers, as they are important steps in farm establishment, however, they were not included in subsequent analysis.

Although an informal and open interview technique was selected as the most appropriate for uncovering rich information, subsequent questions were employed to maintain interview focus and gather consequential information. These questions, derived from informal focus groups, included, but were not limited to, action-oriented questions such as:

- Describe the steps you take in preparing your cocoa farm.
- What are important factors when establishing cocoa on your farm?
- Do you plant/maintain trees when establishing your cocoa farm?
- Do you remove trees from your farm, and why?
- Do you burn or not burn debris left on your farm?
- How do you decide?
- Do you plant food crops? Why or why not?
- Describe the steps you take when maintaining your cocoa farm.
- Do you use fertilizers? Do you think fertilizers are useful?
- How do you adapt to poor production?
- Do you ever alter your practices?
- Can you provide any other information on your practices for maintaining successful cocoa trees?

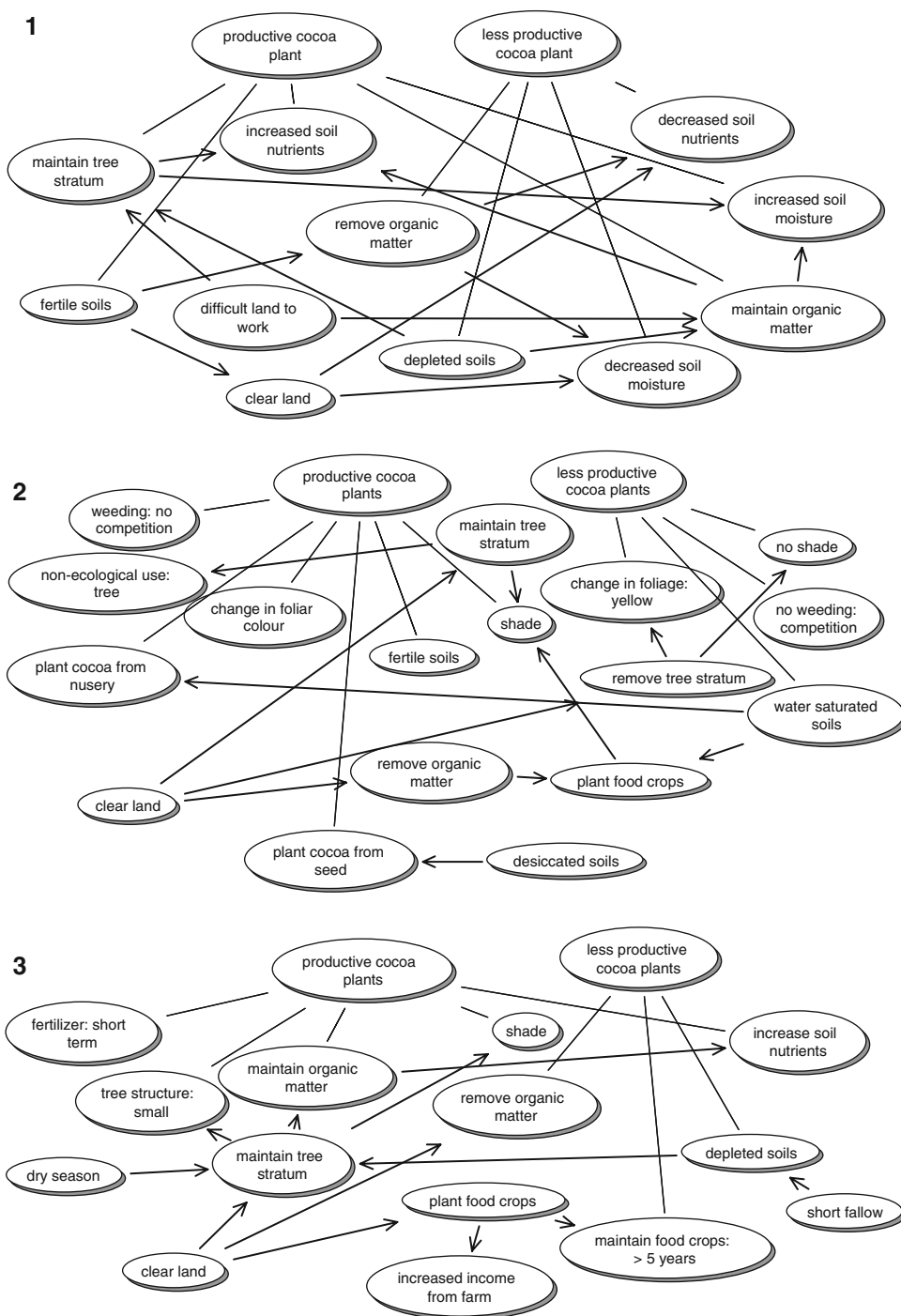
Data Analysis

As this work was exploratory in nature, we followed a grounded theory approach and allowed for emergent steps that may not be common to all farmers. However, key words were identified to represent common steps (variable) in the cognitive map to facilitate comparisons. Each step in farm development was coded into a node and directional arrows to one or more preceding variables, thus making a

continuity map whereby node A is preceded by node B, indicating a cause-and-effect relationship where node A causes node B. The steps taken in establishing and maintaining a farm as stated by the individual farmer were exported in Decision Explorer software (Banxia Software Ltd. 2002), which provides a graphical representation of concepts and links (Fig. 1).

Each individual map was analyzed for the number of variables, connections, connection-to-variable ratio, and

Fig. 1 Three sample cognitive maps of individual farmers. Nodes with text represent farmer-derived variables involved in farm establishment and management. Directed arrows represent links between variables



density (calculated by dividing the number of connections in the map by the maximum number of connections [multiplying the variable number by two to capture both in and out connections for total possible connections]). To allow for identification of key criteria within the process of farm establishment, an analysis of domain and centrality was also conducted. Domain analysis calculates the total number of in and out links (arrows) to each variable, thus revealing the complexity level of each individual node. Centrality builds on domain analysis, providing a wider context by calculating both direct and indirect in and out links (arrows) beyond each node, thus taking into account the interconnectedness of a variable, which may not be immediately connected but may be central to the overall map (Eden and others 1992).

Number and frequency of variables were recorded and subsequently categorized into (1) ordinary and (2) transmitter types. An ordinary variable is one that has both in-arrows and out-arrows, whereas a transmitter variable is an initiating variable, meaning there is a positive out-arrow, but no in-arrows, connecting the variable to the map (Eden and others 1992; Özesmi and Özesmi 2004). These two distinct classes of nodes were employed to reflect a farmer's perception of an individual variable: ordinary and transmitter, or those that appear alterable and those that are fixed, respectively. Means and standard deviations are provided for variable and connection number, connection-to-variable ratio, and both transmitter and ordinary variable frequency ($n = 12$).

Results

Conceptualization of Management Variables

On an individual basis, averaged over the 12 maps, 16 ± 3 variables, 19 ± 3 connections, and a 1.22 ± 0.178 connection-to-variable ratio were found, the latter within the range of expected ratios (Eden and others 1992) (Table 1). High consistency was observed over all cognitive maps, as the mean number of nodes and connections showed minimal deviation (Table 1). Accordingly, there was high similarity between map density values (0.50 to 0.83; Table 2), suggesting that the complexity level of conceptualizing farm establishment and management was similar between participant farmers.

Thirty-eight farmer-defined management variables were identified overall (Table 3). Variables included, but were not limited to, treatment (maintenance or removal) of organic matter, state of existing soils (depleted or fertile), treatment (maintenance or removal) of crop and tree strata, shading (present or absent), changes in soil moisture or nutrients, seasonality, fallow length (short and long), shade

Table 1 Number of connections, number of variables, and connection-to-variable ratio for each case: mean \pm SD ($n = 12$) provided for each cognitive map parameter

Case no	Connections (C)	Variables (V)	C:V
1	25	15	1.67
2	19	15	1.27
3	19	16	1.19
4	22	21	1.05
5	17	14	1.21
6	20	18	1.11
7	21	18	1.17
8	21	15	1.40
9	17	15	1.13
10	17	15	1.13
11	21	21	1.00
12	14	11	1.27
Average	19.4 ± 2.91	16.2 ± 2.89	1.22 ± 0.178

Table 2 Density values for each case, calculated by dividing the number of connections in the map by the maximum number of connections (multiplying variable number by two to capture both in and out connections for total possible connections)

Case no.	Variables \times 2	Connections	Map density
1	30	25	0.83
2	30	19	0.63
3	32	19	0.59
4	42	22	0.52
5	28	17	0.61
6	36	20	0.56
7	36	21	0.58
8	30	21	0.70
9	30	17	0.57
10	30	17	0.57
11	42	21	0.50
12	22	14	0.64

tree structure, and variations in plant competition (represented by weeding techniques).

The most prominent management variable across all maps with the highest domain value (number of links to one variable) was 'maintain tree stratum,' mentioned as the most associated variable in 4 of 12 maps (Table 4). This was not unexpected, as management of the upper shade canopy is frequently the focus of farming practices, either for ecological advantages, such as shade and nutrient additions (Schroth and others 2001; Isaac and others 2007b), or for financial benefits from diversification of farm products (Beer and others 1998; Mercer and Miller 1998). Another substantially mentioned and highly connected variable was 'remove organic matter' (Table 4).

Table 3 List of all management variables mentioned by participating farmers when describing farm management

Variable		
Maintain organic matter	Decreased soil moisture	Desiccated soils
Remove organic matter	Increased soil nutrients	Saturated soils
Maintain tree stratum	Increased soil moisture	Red, loamy soils
Remove tree stratum	No weeding: competition	Short fallow
Establish cocoa plants	Weeding: no competition	Long fallow
Plant cocoa from seed	Shade	Change in foliage: yellow
Plant cocoa from nursery	No shade	Change in foliage: green
Plant food crops	Difficult land to work	Protection of cocoa
Maintain crops: >5 year	Easy land to work	Increased income from farm
Fertilizer: short term	Soil type	Root stratification
Fertilizer: long term	Fertile soils	Nonecological use—tree
Fertilizer: necessary	Depleted soils	Tree structure—small
Decrease soil nutrients	Low soil moisture	

Table 4 The highest domain (number of links to one variable) and centrality (number of direct and indirect links to other variables) variables for each of the 12 cognitive maps

Case no.	Domain variable	Centrality variable
1	Remove organic matter	Remove organic matter
2	Maintain tree stratum	Depleted soils
	Depleted soils	Maintain tree stratum
3	Maintain tree stratum	Maintain tree stratum
4	Plant crops	Shading
5	Shading	Tree structure
	Tree structure	
6	Remove tree stratum	Maintain organic matter
7	Maintain tree stratum	Increase soil nutrients
8	Low soil moisture	Low soil moisture
9	Remove tree stratum	Maintain organic matter
	Maintain tree stratum	
	Shading	
10	Remove organic matter	Plant crops
	Maintain organic matter	
	Plant crops	
11	Maintain organic matter	Decomposition
		Increase soil moisture
12	Remove organic matter	Maintain organic matter
	Maintain organic matter	

Although not necessarily indicating the most important factor, both ‘maintain tree stratum’ and ‘remove organic matter’ represent management steps with a high number of direct links to other variables. Analysis of variable centrality (management steps with a high level of direct and indirect links) revealed slightly differing results. For the most part, ‘maintain organic matter’ was highly ranked as a central variable (Table 4). Across the 12 individual maps,

Table 5 Top six^a highly mentioned variables for both transmitter and ordinary variable type

Variable	
Transmitter	Ordinary
Fertilizer use	Maintain tree stratum
Fallow length	Plant crops
Fertile soils	Shading
Low soil moisture	Remove tree stratum
Depleted soils	Remove organic matter
Dry season	Maintain organic matter

^a For conciseness, only the top six mentioned variables are listed

the ordinary variables, a variable with both in- and out-arrows in the cognitive map, were averaged to 6.8 ± 1.29 . Transmitter variables, limited to variables with exclusively out-arrows, were averaged to 2.4 ± 1.38 (Table 5).

Discussion

Knowledge Use in Agroforestry Management

Processes and Practices

In order to assess the function of a particular variable in the management process, the two variable types, ordinary and transmitter variables (Eden and others 1992; Özemesi and Özemesi 2004), were operationalized. The ordinary variable criterion suggests that these variables are perceived as changeable or alterable, as farmers place such variables in a path of cause and effect. These variables represent 42% of the total variables, indicating that a high percentage of management steps was perceived as accessible and

adaptable, thus allowing multiple points of altering farm practices and a high level of apparent farmer control over successful farm practices. The most frequently referred to ordinary variable was ‘maintaining tree stratum,’ thus supporting this particular concept’s role as a key technique in a farmer’s management process.

Transmitter variables, variables limited to out-arrows, represented only 15% of the variables. These factors may be perceived as inaccessible to or absent from farmer control. For instance, seasonality, soil moisture, soil fertility level, and fallow length were highly ranked variables that showed no or minimal in-arrows; farmers perceived a low ability to alter these mechanisms. Farmers may in fact view these as factors that initiate management response.

Management Indicators

Farmer management included sophisticated use of localized knowledge, particularly explicit indicators, in order to guide management. The variables used as management indicators to guide decision making accounted for 38% of the total. These included farm soil conditions such as soil type (red or brown, dark or black, and light or pale), light and land characteristics, and resultant management effects on plant health, such as foliage color and plant size. Additionally, when evaluating site conditions and overall maintenance of the farm, an emphasis on color of tree bark (white or brown), size of cocoa pods (small or large), and leaf color (green or yellow) was employed as an estimate of cocoa health and productivity. Size and structure of individual cocoa trees were also incorporated into the overall assessment of productivity: tall and narrow versus short and broad trees. Soil characteristics used to signify soil fertility (the ‘strength’ of the soil being either ‘hard’ or ‘soft’), workability (stoniness), and moisture status (position along a toposequence) were jointly used to determine site nutrition and soil water availability.

Knowledge regarding key ecological processes was prominent in establishing and managing cocoa farms as is typical in West African farming systems (Richards 1985) and other agroforestry systems (Schulz and others 1994; Bandeira and others 2002). Specifically, treatment of organic matter (burning organic debris or not) was dependent on site and soil moisture levels, while management of shade trees and food crops (both spatially and temporally) was dependent on site fertility, soil moisture levels, and light infiltration levels through the shade canopy. Previous literature has identified such processes as fundamental in farmer-led management and on-farm experimentation (Grossman 2003). These critical ecologically based indicators were utilized by farmers to improve cocoa productivity. For instance, some farmers suggested that excessive shade contributed to reductions in productivity at

certain stages of the cocoa life cycle. Accordingly, management interventions, such as ring-barking selected trees to reduce farm shade levels, were undertaken. These site indicators, identified by farmers, were incorporated into decision making and management during the life cycle of the farm.

Management Consequences

Ecologically, the potential outcome of each management step is difficult to pinpoint, however, some general statements can be made. Interestingly, these parameters, particularly shade tree effects and organic matter status, are often the focus of ecologically based studies on cocoa agroforestry systems (Beer and others 1998; Schroth and others 2001; Isaac and others 2005). And studies show that the incorporation of shade trees (‘maintain tree stratum’ or other shade tree-based variables) is frequently shown to positively affect cocoa biomass and nutritional status through improved light regulation and nutrient cycling (Beer and others 1998; Schroth and others 2001).

Establishment of understory vegetation (‘plant crop’ variable) provides a course of action to diversify production, maximize land utility, and presumably add to agroecosystem functioning. Although conflicting results exist on the utility of multiple species in agroecosystems (Hartemink 2005; Asare 2006), it remains a critical concept in overall long-term farm development and management.

Certain scientifically based findings contrasted with localized knowledge in the management regimes of farmers. For instance, the majority of farmers mentioned that the presence of trees on the farm increased soil moisture levels, while scientific studies suggest conflicting results on the correlation between soil moisture and the addition of trees (Vandermeer 1989; Smith 2000). Causal differences may be associated with localized site and species-specific knowledge that may be overlooked in the generalization process of scientific knowledge

Critique of Cognitive Mapping for Management Analysis

Cognitive mapping was selected as a suitable qualitative data analysis approach for a grounded theory study on local knowledge and farm management (Strauss and Corbin 1998). Hjørtsø and others (2005) stress that the sociological methods frequently employed to elicit agricultural information are questionnaires, surveys, and rural appraisal participation. These tools may be useful in a particular context, however, they are generally researcher-guided. In contrast, the use of cognitive mapping allows participants to identify variables to include in the qualitative analysis. Since cognitive mapping allowed farmers to state important

concepts to be included in the management process (Swan and Newell 1994), this method proved to be a logical step as an analysis framework for examining management strategies (Jenkins 1998; Robson and Kant 2007). Additionally, as the information provided by farmers was action-oriented (“I do this which leads me to that”), mapping proved a suitable tool to capture the dynamic nature of such information. This technique was useful in examining properties of decision making in farm management as well as contributing to contextualization of local knowledge.

A potential shortcoming of this methodology is limitations on participant number due to the extensive and time-consuming nature of eliciting a detailed cognitive map. However, as suggested in recent work on documentation of local knowledge in an agricultural context (Kiptot 2007), concurrent but diverse methods may be more appropriate to capture accurate local knowledge than simply increasing participant numbers. Therefore, we recommend combining cognitive mapping with other methods of revealing local knowledge to provide a complete analysis, particularly linking individual cognitive maps with community social networks.

Conclusions and Implications

This study demonstrates the active nature of management in a local context and the use of localized knowledge. Process-oriented management and step-by-step decision making using local knowledge indicators emerged as integral components in these agroforests. Key variables were identified in the management process of cocoa-shade agroforestry systems by employing cognitive mapping as a tool-based technique. Consequently, some recommendations can be made. First, we recommend identifying farmer-defined management indicators which may indicate points of introduction for flexible management schemes. Second, it is important to classify variables by their location in the map; those in the path of cause and effect hold a different role than those that initiate management actions. Incorporating and adapting new techniques into a framework of existing management practices may increase agroforestry productivity and resilience. Conceptually, this study supports the bilateral use of knowledge systems, and although larger external forces such as land tenure and regional markets may affect the trajectory of the farm, individual use of knowledge informed by land conditions and access to information remains central to farm development.

Amid complex decision-making processes, the similarity of the cognitive maps suggests a high likelihood of generalizing individual farmer management techniques. This similarity may be strategically beneficial for regional

shifts in agrarian policy toward sustainable practices at the landscape scale. To encourage diversification of farm species and overall farm resilience, an examination of social conditions ought to focus on farmers’ approach to management. Moreover, by exploring the complementary nature of local knowledge to formally derived knowledge on agroforestry management, established practices can be integrated into a larger policy and/or institutional framework.

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