

Socio-ecological niche: a conceptual framework for integration of legumes in smallholder farming systems

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There are numerous examples of technologies with great potential that have not been accepted by smallholder farmers. Quite often, these technologies do not fit well into smallholder systems due to the inherent high level of heterogeneity of these systems. For example, despite their great potential, the adoption of legumes by smallholder farmers in many parts of sub-Saharan Africa has remained poor. A wide range of biophysical (e.g. climate, soil fertility, etc.) and socio-economic variables (e.g. preferences, prices, production objectives etc.) influence the use of legumes in smallholder systems. While some of these variables constrain the adoption of some legumes, others offer opportunities for beneficial use of other legumes in the same system. Therefore, widespread adoption of legumes in smallholder systems can only be achieved if all of the major biophysical and socio-economic constraints are simultaneously identified and addressed. The 'socio-ecological niche' concept proposed in this paper provides the framework through which this might be achieved. The socio-ecological niche, in any given region of agricultural activity, is created by the convergence of agro-ecological, socio-cultural, economic and ecological factors, to describe a multidimensional environment for which compatible technologies can be predicted. The socio-ecological niche concept can be applied in many different contexts in technology development. However, this paper discusses its use with respect to the development of legume technologies. Two case studies are presented to illustrate the concept and to demonstrate its practical significance. The concept is being used in on-going research on legumes in smallholder farming systems in western Kenya.

Keywords: Biophysical, heterogeneity, smallholder systems, socio-economic, technology

Introduction

Legumes have traditionally been grown in many smallholder farming systems in sub-Saharan Africa (e.g. Masefield, 1949; Sturdy, 1939). Attempts to integrate new legumes into smallholder agriculture can be traced to the early colonial period. For example, the first legume introductions into East Africa were in Uganda in 1906 (Byenkya, 1988). Considerable emphasis in the early colonial period was placed on the use of legumes as green manures for soil fertility improvement (e.g. Davy, 1925; Doyne, 1937; Gethin-Jones, 1942; International Institute of Agriculture, 1936). Attempts to introduce legume cultivation on a wide scale included some spectacular failures such as the 'groundnut affair' in Tanzania (Wood, 1950). During this era, mixed farming, modelled after the European mixed-farming system, was becoming established and legumes were seen as important

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components of this system (Sumberg, 2002). Research emphasis was placed heavily on screening for environmental adaptation, with key initial indicators being the legume's ability to establish, grow and survive (Sumberg, 2002). Obviously, significant changes have taken place in smallholder farming systems since the colonial period. Farmers have evolved new farming systems and the increased population density and pressure on land has led to emergence of numerous constraints beyond purely biophysical factors, greatly increasing the degree of complexity and diversity of the farming systems (e.g. Scoones, 2001). In the light of this new reality, it is evident that addressing environmental factors alone cannot be considered adequate for fitting legumes into smallholder farming systems. Despite this, agronomic research has remained focused on growth and performance of legumes at plot scale.

The potential of technologies incorporating the use of legumes is widely acknowledged (Vanlauwe & Giller, 2006). Beneficial effects of green manure, grain and fodder legumes have been reported in numerous publications (e.g. Fujita *et al.*, 1992; Peoples & Craswell, 1992; Sanginga *et al.*, 2001; Wortmann *et al.*, 1994). However, despite this great potential, there has been relatively little success in achieving widespread adoption of legumes by smallholders in sub-Saharan Africa (Sumberg, 2002; Thomas & Sumberg, 1995), particularly those species meant to improve soil fertility (Mapfumo *et al.*, 2005; Wortmann *et al.*, 1994). A similar situation exists with respect to forage legumes. Cultivation of forage legumes remains limited in sub-Saharan Africa despite intensive research over a period of many decades (Thomas and Sumberg, 1995). As a consequence of this, the contribution of food, fodder and soil-fertility-improving legumes to smallholder farming systems has remained far below its potential (Giller, 2001).

Besides the traditionally grown food legumes, (e.g. cowpea *Vigna unguiculata* (L.) Walp.; common bean (*Phaseolus vulgaris* L.), a number of successful but isolated cases exist where non-traditional legume species have been adopted, for example, improved soyabean germplasm in southern Africa (Mpepereki *et al.*, 2000) and West Africa (Sanginga *et al.*, 2003). Stylo (*Stylosanthes guianensis* L.) fodder banks have been widely adopted by West African livestock farmers (Elbasha *et al.*, 1999; Tarawali *et al.*, 1999). However, despite these successes, it is evident that the potential of legumes demonstrated on experimental research farms remains largely unexploited by smallholders in sub-Saharan Africa (Mapfumo & Giller, 2001) and the contribution of food, fodder and soil fertility improving legumes to smallholder farming systems has remained small (Giller, 2001). The modest success of legumes can partly be attributed to lack of appropriate methodologies and tools to stimulate adoption (Amede, 2004), and the need for new and more innovative approaches to identify potential niches for legumes and to facilitate the integration of legumes into complex smallholder farming systems.

Sumberg (2002) suggests that the required characteristics of the legume plant and its associated management can be defined by three sequential contextual levels: (i) socio-cultural, political and economic factors; (ii) agro-ecological factors; and (iii) the production system. These sequential contextual levels form a funnel and technologies emerging from the bottom of the funnel are expected to 'fit well within the larger picture'. While the need for putting technologies in appropriate local context may be generally appreciated, the problem remains as to how this can be achieved in practice.

African smallholder farming systems are highly variable in terms of soil fertility status, labour availability, livestock ownership, cash income, farmer objectives and cultural aspects (e.g. preferences) etc. While these variables constrain the adoption of certain categories of legumes or certain legume species, they also offer opportunities for other legumes to be used beneficially in the same system. This means that it is not useful to give fixed or 'blanket' recommendations for a particular legume technology in a smallholder situation. Instead, efforts should be focused on understanding the biophysical and socio-economic variables, processes and interactions that shape the complex smallholder environment so that these can be factored into the technology development process. This would lead to an appreciation of how the environmental conditions are likely to affect a given legume technology, and eventually, to some rationalization of legume options and conditions necessary for their effective functioning and impact. These environmental conditions constitute the window of opportunity (or *socio-ecological niche*) for the technology in the system.

Our aim is not to develop a rigid prescriptive or predictive procedure or approach. In discussions with agronomists (including crop, soil and livestock scientists) we have found the concept of the socio-ecological niche very useful in discussing how both research and technologies for development can be better tailored to the broad heterogeneity of smallholders and farming systems. This has led us to explore some ideas of how the concept of the socio-ecological niche can be used to aid research and development. In this paper, therefore, we: (i) propose the socio-ecological niche concept as a suitable framework for integration of legume technologies into smallholder farming systems; (ii) define the concept and discuss the factors operating at various levels to delineate the socio-ecological niche; (iii) outline a procedure that could be followed in niche delineation and identification of compatible legume technologies; (iv) illustrate the practical significance of the socio-ecological niche concept in technology development, using appropriate case studies; and (v) suggest the way forward.

The socio-ecological niche concept

Our conception of the socio-ecological niche is analogous to that of the 'ecological niche' of an organism in classical ecological theory. Hutchinson (1957) defines a niche as a region (an *n*-dimensional hyper-volume) in a multidimensional space of environmental factors that affect the welfare of a species (Figure 1). The ecological niche denotes a habitat where organisms of a species can live (where conditions are suitable for life) and the functions of that organism within the ecosystem. Such ecological models attempt to explain the response of biological species to gradients in environmental variables. These variables exert an influence by creating environmental stresses, which together determine an organism's ecological niche (Sibly & Hone, 2002). We simply extend this concept to include a range of other socio-economic (including cultural and institutional) factors that recognize the role of human interest and agency in determining the socio-ecological niche.

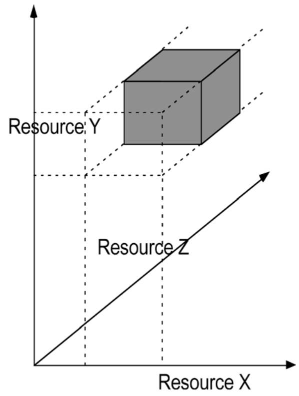

Figure 1 The niche as an *n*-dimensional hyperspace (after Hutchison, 1957)

This concept can also be depicted by visualizing, within a given region of agricultural activity, a series of hierarchical factors (acting as sieves) whose interplay ultimately creates the desired environment for a legume technology (see Figure 2). Starting from the top, agro-ecological factors influence adaptation of the legume to broad-level environmental conditions. The next layer consists of socio-cultural factors, for example, community restrictions and incentives. These have significant influence on technology adoption. Economic factors influence farmer behaviour with respect to technology adoption decisions, while ecological factors operate at the local level and influence adaptation to the local environmental conditions. Institutional support services, for example, input sources, credit facilities, extension services, etc. are crucial to technology innovation and therefore form an integral part of the socio-ecological niche. However, these services are cross-cutting and are therefore not shown as separate layer. All these factors combine to define the niche for a legume technology and are discussed in more detail below.

Agro-ecological factors

Agro-ecosystems are communities of plants and animals interacting with their physical and chemical environment that have been modified by people to produce food, fibre, fuel and other products for human consumption and processing (Altieri, 2002). The main idea implicit in agro-ecological research is that these ecological

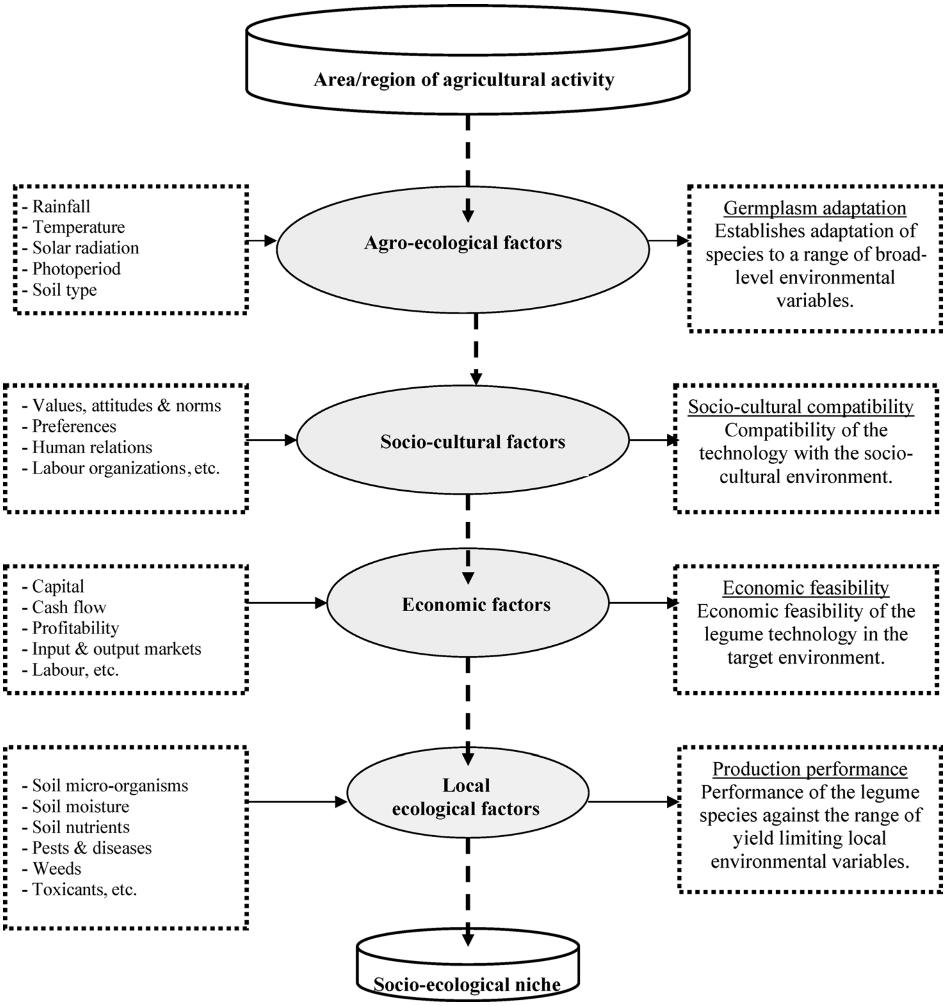

Figure 2 Schematic diagram depicting the concept of the socio-ecological niche, the hierarchical arrangement of factors that influence the delineation of the niche, and the functions and outputs of the factors

relationships and processes can be manipulated to improve production and produce in a more sustainable manner (Gliessman, 1998). Agro-ecosystems operate at different scales. However, in the context of the socio-ecological niche concept, we discuss agro-ecological factors at two scales: (i) the broad scale biophysical conditions to which the legumes must be well adapted (we refer to these as agro-ecological factors); and (ii) the biophysical factors that influence the productivity of legumes at the farm level (we refer to these as local ecological factors). Major agro-ecological factors include precipitation, temperature, solar radiation, photoperiod, soil type, etc. An understanding of these factors allows adapted germplasm to be selected. For example, Keatinge *et al.* (1996, 1998) demonstrated the close linkage between temperature and photoperiod and legume phenology and how these could be used as selection criteria for grain and green manure legumes. Local ecological factors are discussed below.

Socio-cultural factors

Although it is widely accepted that the behaviour of smallholder farmers can be understood in essentially economic terms, 'economic man always operates within a cultural framework which defines the values in terms of which he economizes' (Cancian, 1972). There is, therefore, a fundamental link between the economic and socio-cultural factors, in the manner in which they affect technology development. The socio-cultural factors likely to have greater significance in the determination of the socio-ecological niche include group values, attitudes and norms, land tenure, labour allocation to household and community tasks, organization of labour and marketing, off-farm livelihood strategies, household food demand and supply, and food habits and preferences. There are many definitions of culture. However, with respect to the relationship between culture and development, Harrison (1992) defined culture as a coherent system of values, attitudes, and institutions that influences individual and social behaviour in all dimensions of human experience. The value systems, attitudes, and institutions affect the manner in which any new technology is viewed by a given community and must therefore be seen as independent and causally substantive variables in the process of technology development. It would be wrong to assume that any introduced technology would function effectively and lead to economic prosperity irrespective of cultural setting. Rationalization on the basis of socio-cultural factors provides the appropriate socio-cultural context for the technology. Significant characteristics, requirements and perceptions can be identified and socio-cultural barriers to the use of the technology addressed. The potential role of these cultural factors as causal variables affecting the path of economic growth and development has become a subject of considerable debate (Altman, 2001).

Economic factors

Farmers' decision making about technology adoption are determined largely by biological and economic factors (Winklemann, 1976). Economic factors such as land, financial capital, labour and input and output markets, are major variables that can exert significant effects on the process of technological change. These are the economic factors that co-determine the niche for a legume technology. By shaping farmer perceptions and behaviour, the interplay of these variables produces a unique application domain for the new technology. Levinthal (1998) in a paper on the slow pace of technological change suggests that a new technology is most likely to be commercially viable and profitable in its niche. However, to achieve commercial viability and profitability, the technology must first go through a process of economic rationalization, on the basis of the prevailing constraints, opportunities, goals and interests. In agriculture, this process allows farmers to gain some insight of how the technology might yield returns in future, and goes on in spite of the positive expectations communicated by change agents.

Local ecological factors

Local ecological factors operate at the local level to contribute to the delineation of the socio-ecological niche. In the context of the socio-ecological niche concept, local ecological factors are biophysical variables at the local (or farm) level that constrain legume productivity. Giller and Cadisch (1995) identified the main biophysical factors that limit biological nitrogen fixation (BNF) in legumes as soil nutrient deficiencies, or factors associated with soil acidity, large concentrations of plant-available N in the soil and moisture deficiency. These are good examples of local ecological factors that co-determine the socio-ecological niche for a legume. Other important local ecological factors that have significant effects on the productivity of legumes are pests and diseases, and noxious weeds.

Institutional support services

Access to institutional support services, such as input dealers who would sell to farmers the requisite legume seeds, suitable blends of fertilizer, pesticides, etc, is important for technologies to function. Effective seed systems are of particular importance for legumes. Legume technologies are often information-intensive, therefore access by farmers to appropriate technical information, when and where required, is essential. This implies that farmers should not only have access to extension agents but the agents should also be well equipped with correct information. Meeting household cash needs is a major objective of the farmers that legumes satisfy. Access to functional produce markets is therefore an important aspect of the institutional services environment. A well established institutional environment would be supportive to the use of legume technologies by farmers, leading to multiple benefits of food security, soil fertility, forage for livestock, and cash for households. By their nature, these services are cross-cutting and are therefore not presented separately in Figure 2b.

Towards a definition of the socio-ecological niche

The factors described above, in combination, and including their interactions, delineate the socio-ecological niche for a legume technology. The concept of socio-ecological niche can be adapted and applied in many different contexts, such as in agriculture, manufacturing, and marketing. While a contextual and slightly variable definition of the concept is expected in each of these cases, the general principle remains the same. In the context of agriculture, and particularly in smallholder farming, the socio-ecological niche can be defined as ‘A smallholder farmer environment fashioned by the interactions between assortments of biophysical and socio-economic factors and processes that facilitate functionality and presents to the smallholder the potential to attain desired production objectives’. Applying this concept, the technology and its products would be rationalized not only on the basis of biophysical performance but also on relevant socio-cultural and economic issues, which form part of the socio-ecological niche. Such a rationalization would increase the chances of legume options fitting well in smallholder systems. The socio-ecological niche thus defines the boundaries for legumes within existing farming systems and under existing biophysical and socio-economic conditions. The niche may be dynamic, as changes in, for example, policies and prices can alter the boundaries, increasing or decreasing its size.

The role of the farmer in the socio-ecological niche concept

The farmer is central in defining the socio-ecological niche, since it is the farmer’s production objective, biophysical, socio-economic, and institutional environments that determine the nature of the niche. Therefore, the socio-ecological niche can only be described effectively with reference to the farmer, that is, the type of legume the farmer wants to grow to meet their production objectives and whether the prevailing biophysical and socio-economic environments and the existing institutional framework can support that choice. Thus, legumes that have been adopted by farmers and are found to fulfil farmers’ needs, must have found their suitable socio-ecological niches on-farm. In this sense our concept of the socio-ecological niche shares similarities with the definition of an ‘innovation’ according to Leeuwis and van den Ban (2004), who suggest that a true innovation or ‘complete’ technology exists only if there is an appropriate mix and balance between technical devices and socio-organizational arrangements. The approach we advocate is also in line with thinking associated with an ‘innovation systems framework’ (Hall *et al.*, 2003). Since the farmer is central in defining the socio-ecological niche, and given the differences that normally exist between farmers, there can be numerous socio-ecological niches.

Determining available socio-ecological niches

The four groups of niche-defining factors (see Figure 2) and the cross-cutting institutional factors form the major criteria essential for determining the available socio-ecological niches for legumes in any given region. When the target farmers have been identified, a sixth criterion, the legume production objective, can be added. A procedure that could be followed in matching legumes to appropriate socio-ecological niches is elaborated in Figure 3. In this procedure, which may target individual smallholder farmers or common objective farmer groups, niche screening can be performed in a series of steps. For each niche criterion, several criteria boundaries can be established and used to set the limits for the niche. Information gaps with respect to any niche criterion can be handled by performing an appropriate biophysical or socio-economic characterization. Once all the niche criteria have been examined and criteria boundaries established, the socio-ecological niche

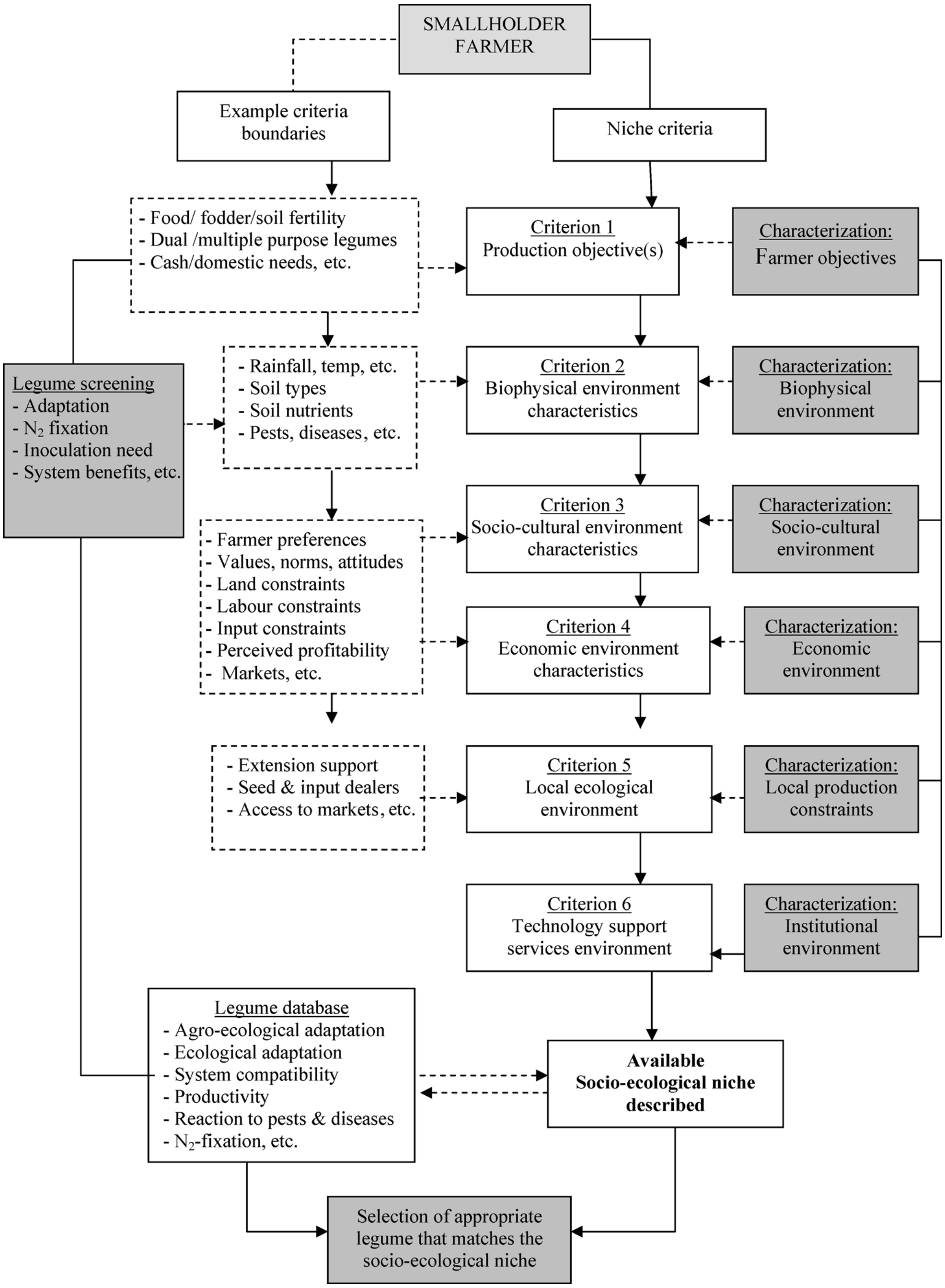

Figure 3 Legume niche criteria, criteria boundaries and the process for the delineation of socio-ecological niche(s), and the selection of potential legumes for the niche(s)

can be fully described. It is the limits imposed on the farmer by these different criteria boundaries that define the available socio-ecological niche(s) and set the stage for the selection of an appropriate legume type(s) for the identified niche(s). Available legume databases can then be consulted to select a legume that matches the identified socio-ecological niche. It is important to emphasize that the entire procedure should involve active participation of farmers. Some examples of how the niche criteria can be used to stratify farmers and assemble the information needed for niche description are discussed below.

Legume production objective (niche criterion 1)

The reason farmers want to incorporate a given legume species in their cropping system is often to meet particular, well-defined production objectives. Having knowledge of these objectives is therefore crucial as it can inform the choice of legume options to be made available to the farmers. The major legume production objectives (Figure 4a) would normally include the need to satisfy household food needs (A_1), to improve soil fertility (B_1), and to improve the quantity and quality of fodder for livestock (C_1). Another important legume production objective is to improve family cash income situation. However, this objective is cross-cutting and is achievable via A_1, B_1, and C_1. In most circumstances, however, farmers seek to satisfy two or more objectives at the same time. These could be food and soil fertility improvement ($A_1 B_1$), soil improvement and livestock feed ($B_1 C_1$), food and livestock feed ($A_1 C_1$), or all the three ($A_1 B_1 C_1$). In such cases, dual or multi-purpose legume types, or different legumes on different fields on the farm, would be the most appropriate options.

Socio-cultural environment (niche criterion 3)

Rural areas, where most smallholders operate, are not as homogeneous as often portrayed. Wiggins and Proctor (2001) view rural areas as consisting of 'peri-urban zones', 'the (middle) countryside', and 'remote rural areas'. Each of these categories has its own unique constraints and opportunities.

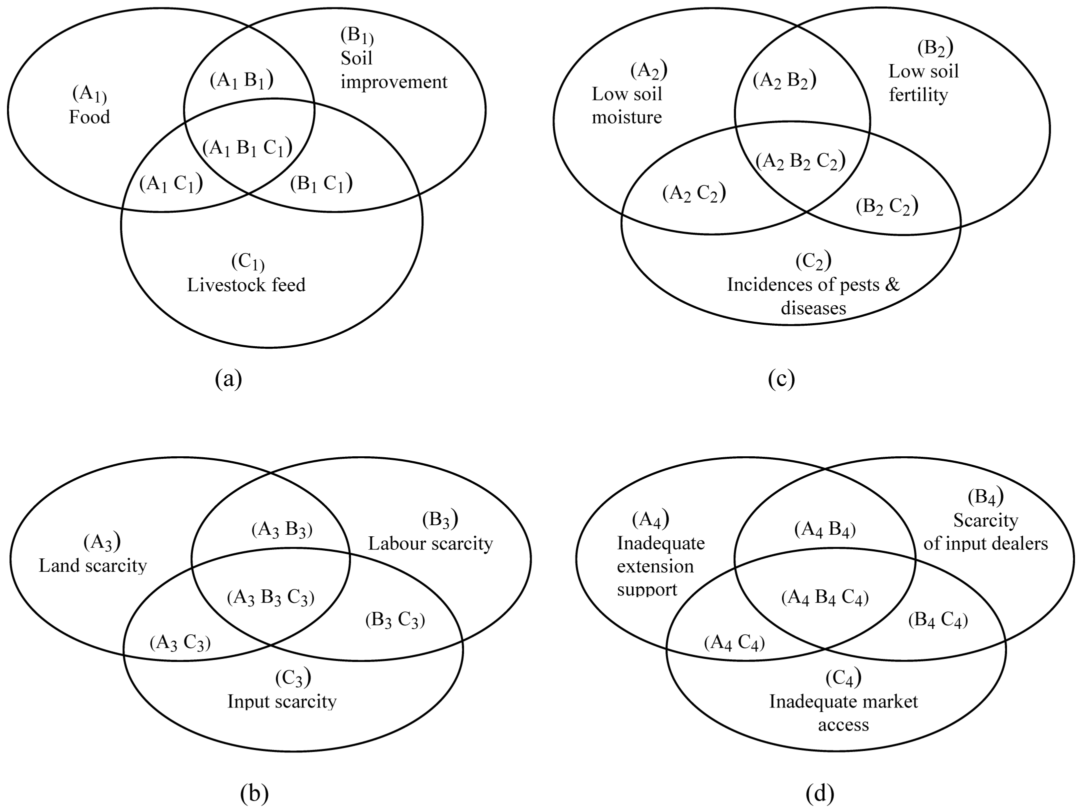

Figure 4 Classification of farmers according to: (a) legume production objectives; (b) scarcity of resources for legume production; (c) local environmental constraints; and (d) access to essential technology support services

For example, the peri-urban zones, due to their proximity to the cities, offer opportunities for market gardening and dairying, while subsistence farming is likely to be a major activity in the remote rural areas. Any surplus production in the remote rural areas has to be of high value to bear transport costs. This means that the role, and by implication the suitable legume type, will be different in each of these rural area zones.

A wide degree of heterogeneity also exists at farm level. For example, Tittonell *et al.* (2005) distinguished five farm types in western Kenya, based on farmers' resource endowment and production criteria. Therefore, based on resource endowment or constraints, farmers constituting an ideal target group for a certain technology can be identified. A variety of distinguishing (socio-cultural and economic factors) characteristics may be used, depending on purpose and relevance. Demographic characteristics, for example, age, gender, household composition (for labour) can be used. Other characteristics of value are those related to attitudes and values (Senauer *et al.*, 1991) of the individuals or the community concerned. Access to on-farm and off-farm sources of income and functional markets may be additional characteristics in this respect. It is also important to establish other aspects of resource endowment, particularly land availability, access to labour, and household income. In the example given in Figure 4(b), a smallholder farmer may have land scarcity (A_3), as an important constraint, labour scarcity (B_3), or input scarcity (C_3). These constraints may also be experienced in combination, thus land and labour scarcity (A_3 B_3), labour and input scarcity (B_3 C_3), land and input scarcity (A_3 C_3), or all the constraints together (A_3 B_3 C_3).

Intercropping and relaying practices enhance the efficiency of land use and are normally embraced by farmers facing land scarcity. Legumes that grow well in association with other crops are likely to be the choice under such circumstances. Labour scarcity is becoming more acute in many smallholder systems. In western Kenya, for example, discussions with farmers revealed a number of factors responsible for this. First, many children can no longer supplement household labour because they now attend school and have to report to school much earlier than they used to. Second, social organizations such as labour groups are no longer active. Community members are becoming increasingly individualistic and commercially minded and expect cash payment for any work done. Third, a majority of smallholder farmers sell their labour to earn cash for household needs. This may lead to delays in farming operations on their own land. There is a high dependency rate which leads to shortage of cash for farm inputs, among others. High incidence of diseases (HIV/AIDS and malaria) and death among family members puts further strain on the meagre cash incomes. Other important socio-cultural issues are those related to farmer preferences, for example, for grain colour, grain size, and taste, especially for legumes grown primarily for household consumption. Although we focus in our examples on western Kenya, where the senior author is based for his research, these lessons are relevant to many intensive smallholder farming systems in sub-Saharan Africa.

Local ecological factors (niche criterion 5)

The biophysical environment of the farmer is important in determining legume niches. Figure 4(c) shows some of the important local ecological constraints. Legume species react in different ways to environmental stress factors such as soil moisture, soil nutrient deficiencies and incidences of pests and diseases. Farmers also experience different combinations of these constraints, for example, low soil moisture (A_2), low soil fertility (B_2), high incidences of pests and diseases (C_2). In reality, however, farmers are faced with multiple, interacting constraints, for example, low soil moisture coupled with low soil fertility (A_2 B_2), low soil fertility and high incidences of pests and diseases (B_2 C_2), low soil moisture and high incidences of pests and diseases (A_2 C_2), or all the factors (A_2 B_2 C_2).

It is necessary to establish the variability in these environmental factors since they contribute to the creation of the niche. For example, in the marginal rainfall Bondo District of western Kenya, a group of farmers narrated how their environmental conditions have changed over the last few decades. They believe that not only has the rainfall declined significantly over the last 20–30 years, but the reliability of rainfall has also decreased considerably over the same period. These changes are attributed to environmental degradation, especially the cutting of trees, which they strongly believe has left their region more vulnerable to drought. Their choice of plant species and varieties to plant is therefore more critical than before. Some of the legume species they used to plant no longer fit well in their cropping system. They gave an example of cowpea, which they used to plant in maize, delayed by a few weeks to reduce competition. This can no longer be done because the rainfall has become so unreliable that delaying cowpea planting by even a week dramatically increases the chances of crop failure. This may explain the disappearance of such legumes in these farming systems.

Soil pH, drainage toxicants, availability of nutrients, especially phosphorus, and other fertility indicators, such as soil depth and organic carbon content, are important aspects of the biophysical environment. For legumes particularly, effects of soil conditions on survival of large populations of effective rhizobia is essential since the host legume–rhizobium association is required for N_2-fixation to occur (Giller, 2001). Presence or absence of particular plant pests and diseases also help to shape the biophysical environment of the farmer.

Institutional support services environment (niche criterion 6)

The institutional support environment of the farmer would either facilitate or impede the selection and adoption of a particular technology. Figure 4(d) details some of the possible constraints with respect to institutional support services environment of the farmer. Farmers may lack adequate information through scarcity of government extension agents or non-governmental organizations (NGOs) in their locality (A_4), have scarcity of input dealers (B_4), and have inadequate market access (C_4). Similarly, (A_4 B_4), (B_4 C_4), (A_4 C_4), and (A_4 B_4 C_4) represent dual and multiple constraint circumstances that farmers may be facing, with respect to institutional services environment. Access to technical information through extension agents, availability of input dealers in the locality, and whether or not farmers have access to markets for produce, will not only strongly influence their decision to grow legumes in general, but also the types or species of legumes they may grow.

The case of western Kenya serves as a good example of the importance of the role of the institutional services in this matter. Although there are few government extension agents in western Kenya, as is the case in the other parts of the country, a fair number of farmers have access to extension services due to a relatively large number of NGOs in the region. However, farm input dealers are still scarce, especially in remote places, so many farmers who may be keen to grow legumes have no access to seeds and fertilizer. Discussions revealed that many also lack knowledge on seed preservation and storage, a fact they believe is responsible for the disappearance of many legume species that used to be grown in the region. With the exception of bean, which is normally intercropped with maize, currently less than 10% of farm areas are devoted to legume cultivation in this region. Seeds of many useful legumes, for example, groundnut and soyabean, do not store for long and farmers need to purchase fresh seed when required. Alternatively, farmers can organize themselves and set up their own seed production units. This requires information and other necessary technical support that can only be available when the institutional support environment is well developed.

Selecting legumes for a niche

Once the ranges of factors influencing potential legume use are established, the next step is to determine which legume species and varieties fit the niche criteria boundaries defined. It is the niche criteria and the criteria boundaries that combine to define the conditions of a particular socio-ecological niche, which in turn, impose limits on legume choice for the niche. In order to properly select legumes that fit socio-ecological niche conditions, a database on legumes is required. Several legume databases that can serve this purpose are available, for example LEXSYS, a decision support tool for integration of legumes into tropical farming systems developed by the International Institute for Tropical Agriculture (IITA) and a legume screening database (LSD) developed by the Kenya Agricultural Research Institute (KARI). Researchers and extension agents can help in gathering and synthesizing the information available in these legume databases and sharing it with farmers, to facilitate the choice of an appropriate legume for an identified socio-ecological niche. Critical information available in these databases include: (i) ecological adaptation; (ii) potential adaptability in target cropping system; (iii) contribution of the legume (e.g. food, fodder or soil fertility); (iv) productivity (e.g. biomass and grain yields); (v) reaction to pests and diseases; (vi) nodulation; and (vii) N_2-fixation capacity, etc.

Case studies illustrating the socio-ecological niche concept

We illustrate the concept of socio-ecological niche by using two case studies derived from western Kenya. The first case study (the black bean) emphasizes the importance of the biophysical component of the socio-ecological niche concept, while the second case study (improved fallows) underscores the importance of the socio-economic (socio-cultural and economic) component of the concept.

Case study 1: the black bean in western Kenya

In most parts of western Kenya, the common bean is an important crop, both for food and cash income. However, the production of this crop was threatened by a number of constraints, including bean stem maggot and bean root rot, whose incidence was quite severe due to low soil fertility status of the smallholder farms in the region. An investigation by Nderitu (1997) identified *Pythium* spp. and *Fusarium solani* as the most important root rot pathogens in the farmers' fields. *Pythium* root rot attacked bean seedlings early in the season and caused high plant mortalities, while *Fusarium* attacked later in the season and caused stunting and poor seed formation. The local varieties grown by farmers (*Alulu, Lipala, Wairimu, Punda* and *Rosecoco*) were highly susceptible to bean root rot pathogens and farmers could no longer produce this crop.

To address this problem, farmers were introduced to an integrated pest management package, which included the use of bean root rot resistant/tolerant varieties from (KARI) – GLP X-92, KK 22, KK 20, KK 15, KK 14 KK, and KK 8. Since KK 15 has black seeds, researchers did not expect it to generate much interest as black seed colour is less preferred by farmers and no varieties with this seed type were grown traditionally. Nevertheless, they included it because it had shown strong resistance to bean root rot pathogens, recording high grain yields in field trials.

A survey of the impact of the new bean varieties was conducted in June 2001, five years after introduction (Odendo *et al.*, 2002). Survey results (Table 1) showed that there was strong farmer awareness of variety KK 15, the black bean, in the two districts: 84% in Kakamega and 98% in Vihiga. Contrary to researchers' expectations, KK 15 was the most widely adopted improved bean variety in Vihiga (80%). In Kakamega, the variety

Table 1 Awareness, adoption and marketability of new root rot tolerant bush bean varieties by farmers in western Kenya

Improved bean variety	*Awareness (%)*		*Adoption (%)*		*Area sown to variety by sampled households (hectares)*[1]		*Mean quantities sold by sampled farmers (kg)*[2]	
	Kakamega	*Vihiga*	*Kakamega*	*Vihiga*	*Kakamega*	*Vihiga*	*Kakamega*	*Vihiga*
KK 8	63	74	34	35	2.0	1.6	21 (2–80)	14 (4–50)
KK 14	20	38	4	5	0.5	0.1	20	5
KK 15	84	98	42	80	2.75	4.2	30 (2–100)	23 (2–160)
KK 20	13	34	2	5	0.05	0.2	4	NA
KK 22	84	92	69	69	12.3	8.3	45 (3–360)	34 (5–200)

Modified from Odendo *et al.* (2002).
[1]Area mean of long and short rain growing seasons.
[2]Range in parenthesis.

was adopted by an impressive 42% of the farmers, coming a close second to KK 22, the favourite small red seeded variety, which had 62% adoption rate. In addition, the mean area allocated to variety KK 15 was the second largest in both districts, indicating the general acceptance of this black seeded bean variety. Farmers were able to sell appreciable quantities of KK 15, suggesting that the variety was not only contributing significantly to farmers' food needs but also to their household income.

This case study illustrates the importance of the biophysical (agro-ecological and local ecological factors) component of the socio-ecological niche concept. The black bean variety met the biophysical criteria (high yield, bean root rot resistant and early maturing) and even though the socio-economic criteria were not immediately met, researchers gambled with it because they believed it stood the best chance of succeeding against the severe onslaught of bean root rot diseases, which had previously rendered bean production impossible in the region. Given the seriousness of the problem, farmers were able to downplay their socio-cultural and economic concerns and rationalize adoption mainly on the basis of biophysical attributes of the variety. Indeed, the black seed colour led to a 'novelty' value of this variety and early adopters earned considerable income from selling seed of the variety to other farmers in the area. The fact that no black seeded bean variety had been accepted before indicates that technologies that do not satisfy the socio-economic aspects of the socio-ecological niche concept might be accepted only in extreme situations, for example, when the very survival of the farmers is threatened, as in this case. Earliness of the variety (74 days to maturity) was particularly important because it meant it is ready for consumption during the February–May hunger period, before the main crop is harvested.

Case study 2: the improved fallow technology in western Kenya

Natural fallow is land left to rest from cultivation for a long period in order to restore soil fertility lost from cropping. Improved fallow, on the other hand, is land resting from cultivation but the vegetation is not natural but managed and planted with species of leguminous trees, shrubs and herbaceous cover crops (Amadalo *et al.*, 2003). The cover crops improve soil fertility in six months (one to two seasons), although studies by Niang *et al.* (2002) concluded that a six-month fallow can yield as much recyclable nutrients as a 12-month fallow. The legumes accumulate nitrogen via atmospheric fixation and in tree and shrub species, the roots access and recycle nitrogen that is at depths otherwise inaccessible to crop roots. The use of improved fallow technology can result in yield increases of between 100–200% (Amadalo *et al.*, 2003). However, the technology requires additional labour for sowing of the tree seeds, cutting the fallows and in preparing the land following a fallow.

The technology, using the fast-growing legume trees *Sesbania sesban* (L.) Merr., *Tephrosia candida* (Roxb.) DC. and *Crotalaria grahamiana* Wight and Arn., was introduced to farmers in 1994 through a collaborative project between the Kenyan Forestry Research Institute (KEFRI) and the World Agroforestry Centre (ICRAF). This pilot project initially covered 17 villages spread in three districts (Kakamega, Vihiga and Siaya) in western Kenya and later on extended to cover some non-pilot villages as well. A detailed study was carried out on the impact of improved fallows on livelihoods by Place *et al.* (2005). Interesting and distinctive adoption patterns emerged inside and outside the pilot area (Figure 5). Inside the pilot villages, the use of improved fallow technology surged rapidly from 1997, reaching about 25% of the households in 1999. This rapid surge was followed by a steep decline in use to only about 13% of the households, after which the pattern appeared to level off at around this figure. In contrast, the use of the technology outside the pilot villages rose steadily from 4.1% in 1997 to 13.7% in 1999, and thereafter levelled somewhat at about 13%. The size of the fallow plots was extremely small, averaging 0.04 ha per farm in 2001. Place *et al.* (2005) attribute the adoption patterns in pilot villages to a high degree of technical support, which may have led to early high rates of testing by farmers. This rise was followed by dis-adoption by those who did not receive sufficient benefits or were unable to manage the technology after ICRAF and partners reduced backstopping efforts. Since 2001, the improved fallows have largely disappeared from farmers' fields in western Kenya. Mango (2002) enumerates a number of factors which may have caused dis-adoption of

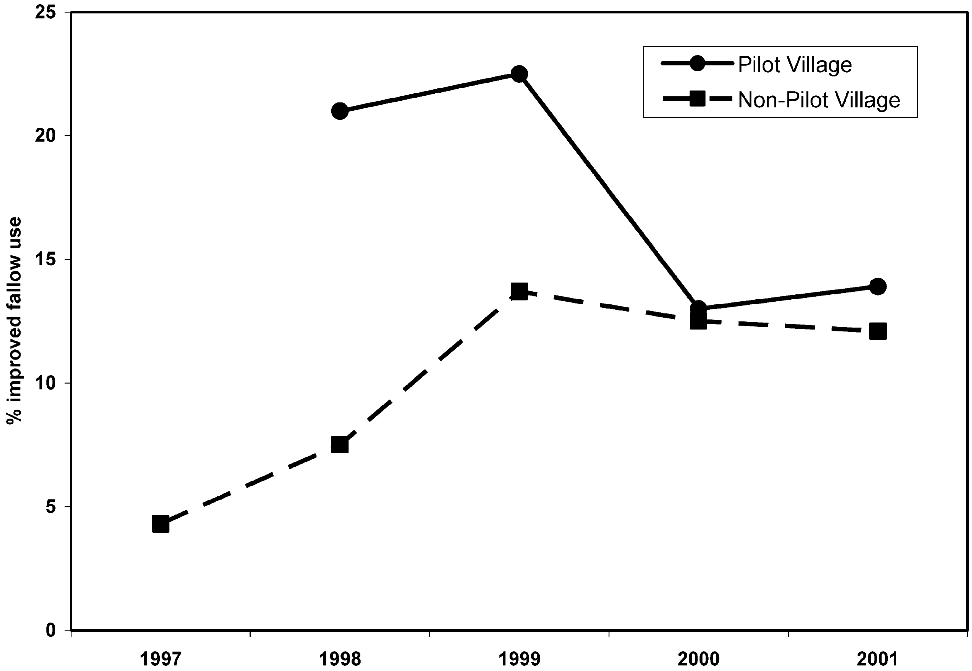

Figure 5 Adoption patterns of improved fallow species by target farmers in western Kenya between 1998 and 2001. Modified from Place *et al*., 2005

improved fallow technology by farmers in the pilot villages. A summary of these include: (1) rock phosphate, which was needed to correct P deficiency, and was supplied through ICRAF support, became unavailable when ICRAF withdrew; (2) women, who generally have many chores, could not successfully manage such a labour-intensive technology; (3) ICRAF and partners provided much technical and material support which ensured the success of the project but not its sustainability; and (4) ICRAF bought improved fallow seeds from farmers at generous prices. Farmers therefore saw improved fallows as a money-making venture and the soil improvement objective became secondary. When ICRAF stopped buying seed, the market collapsed and they saw no compelling reason to continue with the fallows.

This case study illustrates the importance of the socio-economic (socio-cultural and economic factors) component of the socio-ecological niche concept. The differences in the adoption behaviour between pilot and non-pilot villages can be explained by the way farmers rationalize decisions about new practices. Leeuwis and van den Ban (2004) term this the 'evaluative frame of reference', which relates to knowledge and mode of reasoning about the natural, economic and the social world. The evaluative frame of reference incorporates perceptions of technical and socio-economic consequences, perceptions of likelihood and risk, and valuation of consequences and risks *vis-à-vis* aspirations. Applying this analytical framework to this case study, it becomes clear that farmers in the pilot villages, because of the intensive technical and material support from ICRAF, did not find it necessary to go through this process. When later on support was withdrawn and they started rationalizing the practice, the percentage of households using the technology fell rapidly.

Conclusions and the way forward

Strategies for improving the adoption of legume technologies by smallholder farmers should take into account the large degree of heterogeneity in smallholder systems. Due to this heterogeneity, numerous biophysical and socio-economic constraints have to be addressed in order for a technology (e.g. legumes) to fit into the system and generate impact. The necessity for developing technologies that address the realities on the ground is generally appreciated and often the major objective of many projects. However, the fact that many technologies have not been accepted in smallholder systems suggests there are difficulties in practically achieving this objective. The socio-ecological niche concept offers a useful conceptual and practical framework for achieving this. The idea of the niche as being defined by multiple dimensions with which technologies must be compatible, and the procedure of niche screening elaborated here, offer useful approaches. The two case studies presented demonstrate the practical significance of the concept and the need for giving sufficient attention to all the dimensions (biophysical and socio-economic) of the niche so that technologies emerging from the process may fit in well in heterogeneous smallholder systems and be accepted by farmers. This concept is being used in on-going experimental research on legumes together with farmers in Western Kenya, and is potentially applicable to a wide range of technologies in tropical smallholder agriculture.

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