Weeds as agricultural constraint to farmers in Benin: results of a diagnostic study

P.V. Vissoh [1,4,*], G. Gbèhounou[2], A. Ahanchédé[1], T.W. Kuyper[3] and N.G. Röling[4]

[1] Faculté des Sciences Agronomiques, Université d'Abomey-Calavi, 01 BP 526, Cotonou, Benin
[2] Laboratoire de Défense des Cultures, Institut National de Recherche Agricole du Bénin, Cotonou, Benin
[3] Soil Quality Group, Wageningen University, Wageningen, The Netherlands
[4] Communication and Innovation Studies Group, Wageningen University, Wageningen, The Netherlands
* Corresponding author (e-mail: pierrevissoh@yahoo.fr)

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Abstract

Weeds are an emerging constraint on crop production, as a result of population pressure and more intensive use of cultivated land. A diagnostic study was carried out from June through August 2002 in the five agro-ecological zones of Benin (1) to identify the relative importance of weeds among major production constraints, (2) to better understand farmers' perceptions of weed problems, and (3) to take cognizance of their reactions and the different actors involved in weed management technology development. The study also aimed at suggesting the development of weed management strategies that work and are acceptable under small-scale farmers' conditions. Data were collected through semi-structured and unstructured group and/or individual interviews, and through participant observation, transect studies and weed identification during field visits. The results show considerable diversity in biophysical constraints and socio-economic conditions. Population density has led to high pressure on arable land, resulting in land degradation and weed problems. In all situations, pernicious (*Imperata cylindrica, Cyperus* spp., *Commelina* spp.) and parasitic (*Striga* spp.) weeds are difficult to eradicate, causing substantial food crop yield losses and threatening the livelihood of people. Land and labour shortage, low commodity prices and lack of credit were the main constraints hindering weed management. Causes, effects and consequences were analysed, taking into account the socio-economic context. The study's findings with respect to weed management measures, and their adaptation and constraints in using them, suggest that effective and acceptable weed management strategies should be developed, taking into account both biological and social science perspectives with a focus on adding value to indigenous knowledge. Promising strategies for discovery learning about weed management were identified, in order to foster sustainable crop production in Benin.

Additional keywords: cropping systems, indigenous knowledge, participatory technology development

Introduction

Weeds are commonly defined as plants that are unwanted where they grow. This negative perception emerged with agriculture and relates to the damage they cause to crops. In addition to direct competition with crops (or parasitism), weeds cause indirect damage by harbouring insect pests and crop pathogens. Direct losses caused by weeds vary from crop to crop and from one agro-ecological zone to the other for the same crop. The importance of weeds is widely acknowledged and mankind is still far from dealing with them effectively (Rehm & Espig, 1991). Worldwide, 13% loss of agricultural production is attributed to weeds, in spite of the control measures taken by farmers. If no action were taken to protect crops from weeds, the losses would amount to 30% (Oerke *et al.*, 1994). Weeds cause 5% losses in agriculture in the most developed, 10% in the less developed and 25% in the least developed countries. Farmers in the industrialized countries spend more money on controlling weeds than they do on any other pest (Akobundu, 1987).

Weed problems are also reflected in the costs of hiring labour to carry out land preparation and weeding (Doll *et al.*, 1977). Weeding is time-consuming. According to Harsch (2004), out of the total labour input of African women in rice production, 40–60% is spent on weeding. According to Le Bourgeois & Marnotte (2002) about 60% of the time in farming is spent on the first clearing of the farm and on weeding, representing 140–190 man-days per ha.

The detrimental effects of weeds in Africa far exceed the world average. It is estimated that in Africa yield losses range from 25% to total crop failure, depending on many factors among which weed pressure, availability of improved weed control technology, cost of weed control and level of weed management practised by farmers (Akobundu, 1987; Van Rijn, 2000). The majority of farmers in Ghana identified weeding as the main constraint in their farming system, with a major effect on yields (Amanor, 1994). In Benin, investigations carried out in the different agro-ecological zones revealed that weeds are a serious constraint on crop production (Carsky *et al.*, 1994; 2003; Gbèhounou, 1998; Chikoye *et al.*, 1999; 2002; Ahanchédé, 2000; Gbèhounou & Adango, 2003). Spear grass (*Imperata cylindrica*) interference can cause crop yield losses as high as 80% in cassava and 50% in maize (Koch *et al.*, 1990; Chikoye et *al.*, 2001). *Striga* caused total crop losses on over 15,000 ha and was present on about 20,000 ha of fallow land, parasitizing wild hosts (Favi, 1986). Only in newly opened land is weed infestation limited and one weeding is enough to get a good yield. Weed problems have been aggravated and have become particularly acute as a result of population pressure, of shortening or eliminating fallow periods, of scarcity of labour, and of the collapse of commodity prices, particularly of cotton. This listing makes clear that weed problems need to be understood in the context of both the biophysical (soil, crops) and the socio-economic and political environment. In Benin, weeding is one of the most difficult and stressful farm operations. The drudgery associated with weed control is due to hand weeding, which is the method used by the majority of farmers. Family labour is seriously stretched on large farms and has to be deployed continuously for weeding, as the first weeded plots are re-infested by the time the last plots are cleaned. Farmers have no rest and sometimes have to give priority to other farm (and non-farm) activities based on opportunity cost (P.V. Vissoh, personal observation). In Benin, technical crop production recommendations of the non-governmental organization (NGO) 'Sasakawa Global 2000' (SG2000) illustrate the importance of weed problems. As an example, SG2000's maize production package places a great deal of emphasis on weeding, because applying inorganic fertilizers and not weeding favours weeds in the competition with maize and results in severe yield losses. So it is compulsory to weed twice and local extension agents are asked to assist the farmers during the implementation of each component of the package (Galiba, 1993). This maize package was strictly applied as extension agents travelled around to ensure a closer contact with farmers and farmers were made a loan in kind (seeds, fertilizers and pesticides). The majority of farmers could not continue to adopt this package as SG2000 first reduced its financial support to two years and finally withdrew it completely. The history of this package is that management schemes with disregard for the questions (1) What works?, and (2) What is acceptable, resulting in farmers' self-reliance?, have a good risk of failure.

The results of a technographic study conducted in Benin (Kossou *et al.*, 2001) indicated that in spite of existing indigenous knowledge and technical recommendations, farmers expressed an urgent need for innovations in weed management that are both technically successful and socially acceptable. Given these results, it seemed that the decision to focus research on weeds was justified. Nevertheless, it was important to carry out a diagnostic study involving all stakeholders concerned to get a closer view of the weed problems experienced by farmers and to identify constraints on weed management as well as potential solutions. The diagnostic study should also help to place the weed problem in the context of agricultural changes that may cause the emergence of new weeds.

Having chosen weeds as a constraint on crop production, the objectives of the diagnostic study were to:

1. Clarify to what extent weeds constitute a constraint on crop production compared with other agricultural constraints;
2. Appreciate farmers' perceptions of weed problems, and identify prevailing solutions;
3. Assess how effective these solutions are;
4. Select – with farmers – promising weed management strategies to be used in the design of experimental fieldwork;
5. Identify villages, farmers and other stakeholders to work with in a participatory weed management technology development.

The aims of the subsequent research phase, which includes experimental fieldwork, are participatory learning among all stakeholders about effective and appropriate technologies for weed management, farmers' empowerment, and the development of components of a curriculum for a 'farmer field school' with weeds as a central focus. But other aspects of crop management to let farmers gain a more holistic understanding of ecology and hence ways of growing a healthy crop are not excluded.

Materials and methods

Study area

The diagnostic study was carried out in the five agro-ecological zones defined by the National Agricultural Research Institute of Benin (Anon., 1995). For the different agro-ecological zones and their characteristics see Table 1. The map in Figure 1 shows the location of the agro-ecological zones and the villages that were visited during the diagnostic study.

Table 1. Characteristics of the five agro-ecological zones of Benin. Source: Anon. (1995).

Agro-ecological zone	Relative area (%)	Annual rainfall (mm)	Climate	Soil type[1]	Natural vegetation	Main crops[2]	Land holding
Southern Zone	13	1000–1400	Subequatorial, with two rainy and two dry seasons	Ferralitic	Relics of forest	Maize, cassava, cowpea, oil palm, vegetables	Inheritance, purchased
Transition Zone	15	1000–1200	Transitional (no clear distinction between the two rainy seasons)	Tropical ferruginous	Arboreous savannah	Maize, cashew, cassava, cotton groundnut, yam	Inheritance, rented
Southern Borgou Southern Atacora Zone	32	900–1300	Soudano-Guinean One rainy and one dry season	Tropical ferruginous	Arboreous savannah	Sorghum, cotton, maize, yam	Inheritance
Northern Borgou Zone	24	600–800	Soudano-Sahelian One rainy and one dry season	Tropical ferruginous	Shrubby savannah	Cotton, maize, millet, sorghum	Inheritance
Atacora Zone	16	900–1200	Soudanian One rainy and one dry season	Tropical ferruginous	Arboreous savannah	Sorghum, cowpea maize, millet	Inheritance

[1] FAO classification.

[2] Most important crop first, other crops in alphabetical order.

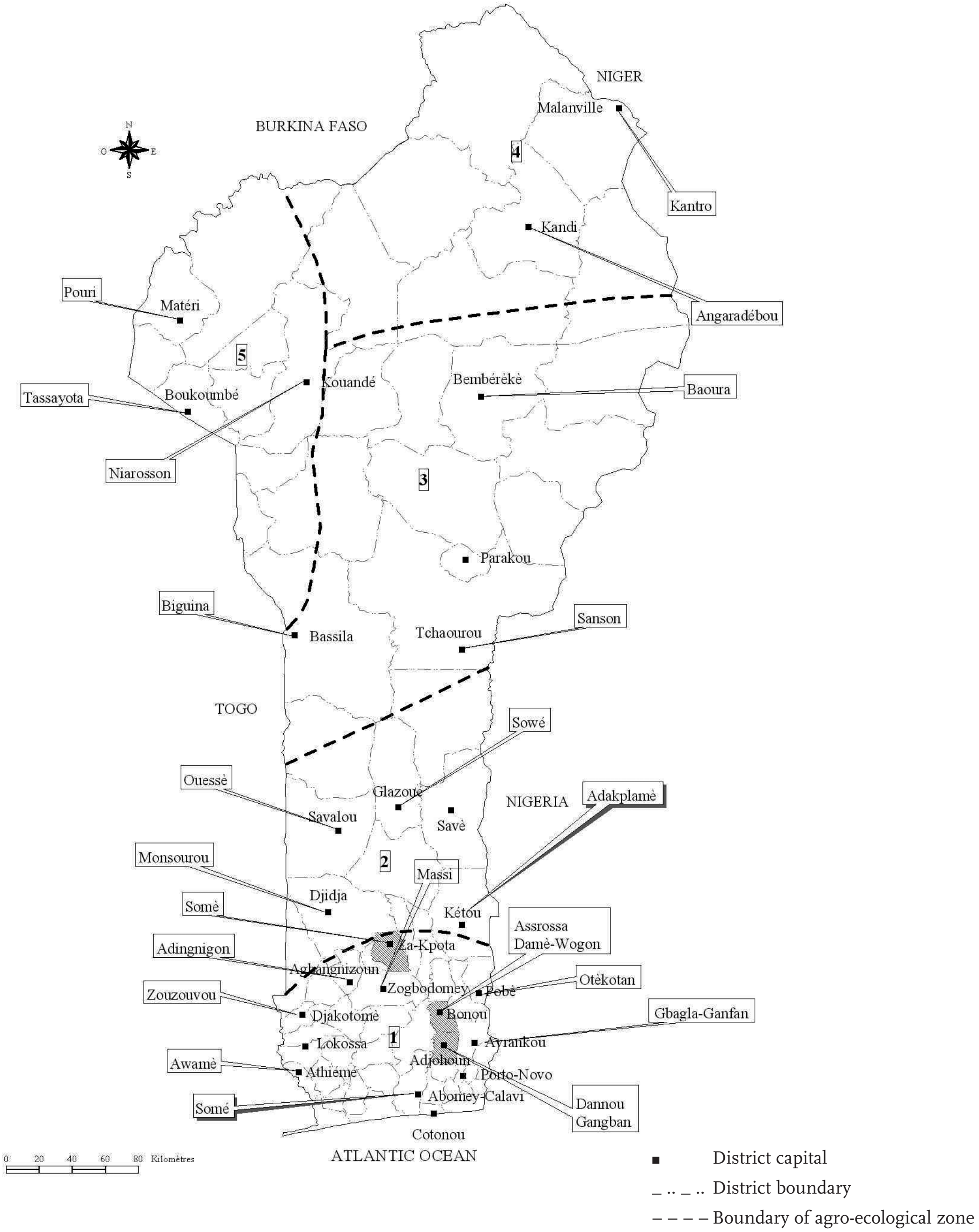

Figure 1. Map of the Republic of Benin, indicating the 5 agro-ecological zones (1–5), the villages visited during the study and the districts selected for the in-depth studies (hatched). 1 = Southern Zone, 2 = Transition Zone, 3 = Southern Borgou/Southern Atacora Zone, 4 = Northern Borgou Zone, 5 = Atacora Zone.

The choice of agro-ecological zones as entry points was based on the assumption that different types of climate and soil would result in different cropping systems and consequently in different weed species and weed problem perceptions by farmers. Twenty-four (24) villages were selected with a minimum of two villages per agro-ecological zone.

Data collection

Preparatory phase

Before choosing the villages where the study was to be conducted, in each agro-ecological zone preliminary discussions were organized with officers at the headquarters of extension services, scientists at research centres and representatives of NGOs, in order to introduce the objectives of the study and seek advice on districts and villages worth investigation. In each agro-ecological zone a number of districts were selected based on population density, type of soil and ethnic groups. It was assumed that different population densities could result in different pressures on land, different types of soil could lead to different weed species, and different ethnic groups could manage emerging weeds differently. The villages were selected based on (1) the above-mentioned three criteria, (2) the availability of people willing to co-operate, (3) the intervention of different institutions (research, extension and NGOs) and (4) their accessibility. Some of the villages were chosen to get a better understanding of how farmers were involved in the 'Approche participative niveau village' (participatory approach at village level) in identification of constraints, and in the development and diffusion of innovations. About half the number of villages was chosen in the Southern Zone because of its high ethnic diversity. Furthermore, more than 60% of the total population of Benin lives in that zone, resulting in high pressure on arable land.

Visits to selected districts and villages were made together with the district extension officer, NGO staff at the district level, and local extension agents. Subsequently, the researcher revisited the villages selected on the basis of the predefined criteria, and the planning of the diagnostic study for each selected village was made and sent to each district extension officer who in turn sent it to the local extension agent.

Implementation phase

For data collection, the local extension agents helped to contact the chief of each village who provided information on existing farmer groups. In each village, there are farmer organizations called 'Groupements Villageois' (GV) with special access to resources including male and female cotton growers, and 'Groupements Féminins' made up of women engaged in the processing of agricultural products. Appointments with farmers were made together with the leader of the farmers' group and the local extension agent.

The research methods and techniques comprised visits to farmers' fields, unstructured and semi-structured group and individual interviews, participant observation and transect studies. Transect studies were carried out to verify information provided by farmers on soil types and weed species. The tools used were village maps and check-lists, and the illustrated handbooks of Akobundu & Agyakwa (1989) and Johnson

(1997) for the identification of weed species. Apart from the farmers, who constituted the main group of interviewees, input traders, NGO representatives, leaders of farmer organizations and researchers and extension officers were interviewed too. The checklist used for the interviews focused on (1) production systems, (2) production constraints, (3) causes, effects and consequences of continuous cropping, (4) causes, mechanisms, effects and consequences of weed infestation, (5) farmers' perceptions and concepts of weeds, (6) major weeds and their agronomic and economic importance, (7) farmers' strategies to cope with weed problems, (8) reasons for adoption and non-adoption of recommended weed control technologies, (9) economic and institutional environment, and (10) social environment (land tenure system, traditional land rights and access to land, sources and cost of labour). During field visits, direct observations enabled an inventory of weed species, and an assessment of their local names.

A total of 386 farmers were interviewed in the five agro-ecological zones. Both men and women were interviewed in groups, or individually. Twenty-four farmer groups were interviewed comprising 180 men and 50 women, and 51 men and 105 women were interviewed individually during field visits and identification of weeds.

Data analysis

A typology of production systems was made, based on soil type, farm size, degree of agricultural intensification, integration of arable farming and livestock, and rainfall. This typology enabled us to identify the major weeds in the different production systems and to better understand weed problems and farmers' weed control strategies. The production systems in each agro-ecological zone were described and, based on similarities, they were grouped into three main categories. Production systems in every agro-ecological zone were described and analysed with farmers as suggested by Mutsaers *et al.* (1997), taking into account variables such as labour, land availability, credit accessibility, commodity prices and degree of mechanization.

Data collection was combined with a participatory interpretation with farmers in the field or during group discussions. Land rights and land use systems in the different agro-ecological zones were analysed with regard to emergence of weed species. Weed control strategies developed either by research or through farmers' local knowledge and practices were analysed in terms of their popularity, adaptation and effectiveness. The constraints hindering agricultural production were ranked with farmers. All collected data were validated with farmers during group meetings.

Results and discussion

Production systems

Southern Zone

The Southern Zone covers approximately 13% of the total area of the country where more than 60% of the total population of Benin live. Production systems in the Southern Zone are characterized by a high population density estimated on average at 323 inhabitants km^{-2} (Table 2) according to the 'Institut National de la Statistique et de l'Analyse Economique' (Anon., 2003a), resulting in a strong pressure on arable land (Brouwers, 1993). The Malthusian, or more recently Neo-Malthusian view is that increasing demographic pressure results in overuse of reasonable quality land and/or the misuse of marginal, often easily degradable land (Barrow, 1991).

In traditional production systems in West Africa where population density is low, shifting cultivation is widespread. Consisting of cropping the land for three to four years and leaving it to fallow for more than 10 years, shifting cultivation has become something of the past due to the population increase. This abandonment has two major reasons, one is due to soil fertility decline and the second is weed problems, which farmers cannot cope with as the cropping length is prolonged (Akobundu, 1987). Fallow periods are essential in the process of eradication of annual and perennial weeds such as *Commelina benghalensis, Cyperus rotundus* and *Imperata cylindrica* (Le Bourgeois, 1993). The shortening and even abandonment of fallow periods due to demographic pressure and the increasing food demand have favoured the proliferation of witch weed (*Striga* spp.) (Sallé & Raynal-Roques, 1989). Traditional fallow periods are no longer observed, except in areas such as Pobè and Bonou, where few farmers claimed that they still practise fallow periods of four to five years (Table 2). However, such fallow periods are not enough for soil fertility restoration and weed control. According to Pieri (1989), prolonged fallow periods of 10 years in dry savannah areas and up to 30 years in humid areas are needed to stabilize traditional production systems like shifting cultivation. However, there are production systems that enable land cultivation over many generations without reaching an alarming threshold of weed infestation.

Animal husbandry is limited to small ruminants and poultry. Hand tools such as the hoe and the cutlass are used in low external-input subsistence farming where staple food crops such as maize, cassava and cowpea are grown (Table 1). Cotton was grown to a lesser extent but is now being abandoned due to the recent cotton crisis. This change, which removes an entire crop out of the rotation, has a tremendous effect on fertilizer use, reduces income, takes money out of farming that could have been used for weeding and other farming activities. The implications of this change are more extensively discussed by Sinzogan *et al.* (2004). Up to now, this production system has coped with population increase and has been able to meet its food demand. The debate is about the question whether such land use systems are irrevocably going to collapse because of the mining of nutrients or whether African farmers have evolved an albeit more intensive and less productive but still stable system.

Land is mostly inherited (Table 1) and extremely fragmented. Holdings average less than 0.2 ha and some young people do not own land. Most agricultural activities are carried out with family labour. Women are mostly engaged in processing agricultural products and in petty trading. Hired labour is sought seasonally to complement family labour, as kids are sent to school as a result of government policies that reduced school fees for boys and exempted girls from paying school fees altogether. Furthermore, landless young people have shifted from agricultural activities to off-farm activities, such as motorcycle taxi transport in the cities, selling fuel on the black market, and distilling palm wine into a popular, local liquor. These patterns of

Table 2. Demographics and main constraints of the villages explored in the five agro-ecological zones of Benin. Constraints ranked per village in order of importance.

Zone/village	Population density[1] (persons km^{-2})	Fallow period (years)	Main constraints identified				
			Rainfall	Soil fertility	Weeds	Pests[2]	Other[3]
Southern Zone							
Gbagla-Ganfan	1031	No fallow	1	2	3	4	
Dannou, Gangban	202	No fallow			2	1	3,4
Assrossa, Damè-Wogon	119	4	1	2	4	3	
Otèkotan	207	5	1	2	3	4	
Somé	571	No fallow	1	2	3	4	
Zouzouvou	412	No fallow	1	2	3		4
Awamè	166	No fallow	1	2	3		4
Adingnigon	225	No fallow	1	2	3	4	
Massi	88	Negligible		4	1	2,3	
Somè	213	No fallow	1	2	3	4	
Average	323	No fallow	1	2	3	3	4
Transition Zone							
Adakplamè	57	5–7	1		2	4	3
Monsourou	39	5–6		3	1	2	4
Ouessè	39	5	1	2	4	3	
Sowé	51	4–5	1		3		2,4
Average	47	5–6	1	2	2	3	3
Southern Borgou-Southern Atacora Zone							
Sanson	15	6–7	1	4	2	3	
Baoura	28	10	1	3	2		4
Biguina	13	4–5	1	3	2	4	
Average	19	7	1	3	2	4	4
Northern Borgou Zone							
Angaradébou	28	5–10	3		1	4	2
Kantro	34	3	3	1	2	4	
Average	31	4–10	3	1	2	4	2
Atacora Zone							
Niarosson	25	6		4	1	3	2
Pouri	48	3	2	3	1		4
Tassayota	58	6	1	2	3	4	
Average	44	5	2	3	2	4	3

[1] Population density of the districts where the villages are located. Source: Anon. (2003).

[2] Including insects and rodents.

[3] Constraints that were only mentioned once (dyke management, equipment, labour, marketing, roaming farm animals), twice (credit, conservation, post-harvest) or three times (storage).

(temporary) migration explain why labour has become scarcer.

The main production constraints identified and ranked by farmers are presented in Table 2. Rainfall was mentioned as the first constraint in 80% of the villages explored in the Southern Zone. According to farmers, there is a substantial decline in the amount of annual rainfall. More importantly, rainfall frequencies and distribution are more erratic and have altered the cropping calendar. Observing that the onset of the rainy season has shifted from March to April, farmers compare agriculture to gambling. In the Southern Zone, the climate is characterized by two rainy seasons (a major or long and a minor or short one), each followed by a dry season (a short and a long one). The short rainy season has become so erratic that farmers do not expect good yields from the crops grown in that period. Ahlonsou (2002), studying the variability in rainfall regimes in Benin over the period 1941–2000, observed a decrease in the amount of annual rainfall during the period 1971–2000 compared with that of 1941–1970. This decrease is even significant in the northern part of the country. He showed that the amount of rainfall in September tends to be the same as that in October, i.e., the peak of the rainfall during the short rainy season has shifted from October during 1941–1970 to September during the period of 1971–2000. Considering that the short rainy season normally starts in mid-September, this shift in the peak of the rainfall from October to September may be detrimental to crops, as they may not receive sufficient rainfall to complete their growth cycle. A general characteristic of the amount of rainfall per decade from three meteorological stations in the Southern Zone partly confirms farmers' observations. The decades after 1971 have been distinctly drier than the decade 1961–1970, although it may not be easy to derive a long-tem trend from these decadal data. The second (1971–1980) and fourth (1991–2000) decades, averaging 1000 mm in Adjohoun and Aplahoué, were drier than the third decade (1981–1990). A similar trend was observed at Bohicon. These observations are consistent with the findings of Houndenou (1999) who showed that the increased variability in rainfall is also due to a decrease in the number of rain days.

Next to changes in precipitation pattern, also other factors could have resulted in lower harvests. Agricultural intensification has obviously caused a decline in soil organic matter content and hence led to a lower water-holding capacity of the soil. As a consequence, the rainfall use efficiency (plant productivity per mm rainfall) may have decreased.

Transition Zone

Human population density in the Transition Zone, averaging 47 inhabitants km^{-2}, is lower than in the Southern Zone, resulting in less pressure on arable land than in the Southern Zone (Table 2) (Anon., 2003a). Fallow periods range from 4 to 7 years, depending on land availability. In the Transition Zone there is no clear-cut distinction between the two rainy seasons. The average rainfall is also lower in the decades since 1970 than in 1961–1970. Farmers used to grow cotton. All cotton growers recognize that food crops, especially maize, benefit from the residual effects of inorganic fertilizers applied to cotton, resulting in an extension of the cropping period of their plots.

Apart from small-ruminant husbandry and poultry, there is an attempt to rear oxen by a few richer farmers in an attempt to use draught farming to expand their cotton area. As in the Southern Zone, agriculture is not associated with livestock. Family labour is the main source of labour for agricultural activities, supplemented by hired labour. Farm size ranges from 2 to 20 ha and some landlords have even more. Land is inherited. Land is not sold or leased but land is not given free of charge either. Migrants usually have access to land without any particular arrangement if they express the need but they are not allowed to plant trees as tree-planting means that you claim ownership for a long time, which also is a sign of land appropriation in the long run. In this respect, the traditional saying 'that a shepherd does not say that a goat is pregnant when its owner wants it back' implies that landowners can deprive tenants from the leased plots at any time when they want their land back. This land tenure insecurity does not encourage tenants to adopt long-term soil and weed management practices (Saïdou *et al.*, 2004).

Borgou-Atacora Zone

The production systems of the Southern Borgou-Southern Atacora Zone, the Northern Borgou Zone, and the Atacora Zone are taken together as production systems of the Northern Zone, because of the similarities among them, particularly with regard to soils and rainfall patterns.

The production system in northern Benin is characterized by an even lower population density than in the Transition Zone (on average 27 inhabitants km^{-2}) (Table 2). Apart from Malanville, Matéri and Boukoumbé Districts where there is a strong population pressure on the land due to the fact that a large proportion of the land belongs to the national park where farming is prohibited and because of the presence of mountains, land is still plentiful and farmers cultivate from 3 to 30 ha. The rainfall pattern is unimodal. Over the period 1970–2000, the amount of rainfall per year has varied considerably, with a severe decrease in the third decade (1981–1990), averaging 1000 mm in the Southern Borgou-Southern Atacora Zones and about 750 mm in the Northern Borgou Zone. Livestock is quite developed and is integrated in the arable farming activities. In addition to the implements used in the other production systems, farmers use draught power or tractors to expand their areas and maximize profit. In 50% of the explored villages farmers ranked rainfall as the first constraint, while weeds were ranked first in 38% of the villages. Low soil fertility was not the first constraint to farmers in the northern zones except in the Boukombé, Malanville and Matéri Districts where land availability ranked first (Table 2).

Weed problems

In all the villages explored in the Southern Zone, farmers mentioned weeds as an important constraint on crop production. Major weed species identified and ranked by farmers included *Imperata cylindrica* (spear grass) as a major weed in 70% of the villages, *Striga* spp. (witch weed) in 20% of the villages and *Leersia hexandra* in the valley in 10% of the villages (Table 3). Spear grass is also a major weed in Adingnigon and Somè. According to the farmers interviewed, witch weed causes more damage than spear grass and it is easier to reclaim plots infested by spear grass than plots infested with witch weed, which apparently nobody can control. Other major weeds are

Table 3. Major weeds of the villages explored in the five agro-ecological zones of Benin, ranked per village in order of importance.

Zone/village	*Imperata cylindrica*	*Cyperus* spp.	*Commelina* spp.	*Digitaria horizontalis*	*Striga* spp.	Other[1]
Southern Zone						
Gbagla-Ganfan	1	2	3	4		
Dannou, Gangban			4			1,2,3,5
Assrossa, Damè-Wogon	1	2	3	4		
Otèkotan	1		3	4		2
Somè	1	4	3	2		
Zouzouvou	1	4	2			3
Awamè	1		2	4		3
Adingnigon	2	3		4	1	
Massi	1	2	3	4		
Somè	2	3	4		1	
Average	1	3	3	3	1	–
Transition Zone						
Adakplamè	1	2	3			4
Monsourou	1	3	2	4		
Ouessè	1	2	3			4
Sowé	1	3	2			4
Average	1	2	2	4		4
Southern Borgou-Southern Atacora Zone						
Sanson	4		2	3	1	
Baoura			1	4	3	2
Biguina	1	3	2			4
Average	2	3	2	3	2	3
Northern Borgou Zone						
Angaradébou		3	2	4	1	
Kantro		3	2		1	4
Average		3	2	4	1	
Atacora Zone						
Niarosson			2	4	1	3
Pouri			2	3	1	4
Tassayota	4	2		3	1	
Average	4	2	2	3	1	3

[1] Weeds that were only mentioned once or twice (*Ageratum conyzoides* (2×), *Brachiaria* sp., *Eichhornia crassipes, Echinochloa pyramidalis, Ipomoea* spp., *Leersia hexandra, Mariscus alternifolius, Paspalum vaginatum, Rottboellia cochinchinensis* and *Tridax procumbens*).

Cyperus spp. and *Commelina* spp. The local names of some troublesome weeds such as *Commelina* spp. and *Striga* spp. indicate the damage they cause to crops and human beings. *Commelina* spp. are called *glessikoumakou* in Fon and derived languages, which means 'stays until the farmer dies'. This implies that this weed is difficult to eradicate. It resists most control measures including herbicides. Farmers' perceptions agree with research findings of Deat (1990) and Ahanchédé (1994). *Striga* spp. are called *do* in Fon, which means 'death', indicating that there are no real solutions to overcoming this weed.

Farmers revealed that adaptation of weeds to the changing cropping systems and the weeds' quick regeneration compels them to increase the number of weeding rounds. An old man of 70 years noted that a field should not be left for more than a week because by that time weeds would have re-infested it. So weeds do not give farmers any respite. Interviewed farmers were asked to compare the time devoted to weeding with the time spent on farm activities like land preparation, ploughing, sowing, and harvesting. The question asked was if the time devoted to farm activities were divided into four equal parts, how many parts would they allocate to weeding? The farmers interviewed stated that they would devote more than two parts or more than 50% of their time to weeding. They also acknowledged that untimely weeding results in severe crop yield losses.

Lack of labour is another bottleneck. Weeding is mainly done by family labour. Hired labour has become scarce and costly. Based on farmers' estimates, 12,500 F CFA (€ 19) to 20,000 F CFA (€ 30.5) is paid in cash to manually weed one hectare depending on labour availability, weed species and the degree of infestation. In addition, the labourers ask for food and drinks. Weeding costs are higher if the plots are infested with spear grass. In this case manually weeding one hectare costs between 40,000 F CFA (€ 61) and 50,000 F CFA (€ 76). An alternative to hand weeding is the use of herbicides, but farmers consider their prices prohibitive. For example, to treat one hectare with herbicides would cost between € 25 and € 30, which is virtually the same as paid for hand weeding (Table 4). On the other hand, farmers consider the clearing of plots infested with spear grass by using herbicides more beneficial than

Table 4. Herbicides used in cotton, maize and rice, and costs of hand weeding versus herbicide application.

Crop	Herbicide	Active ingredients	Application rate ($l\ ha^{-1}$)	Price (€ l^{-1})	Costs (€ ha^{-1})	
					Hand weeding	Herbicide application
Cotton	Kalach 360	Glyphosate	3	8.54	9–38	25.60
	Callifor G	Alachlor, atrazin, glyphosate	3	8.54	9–38	25.60
Maize	Primagram 500	Metolachlor, atrazin	4	7.22	9–38	30.50
Rice	Garil	Triclopyr, propanil	5	11.60	57[1]	57.93

[1] In rice mostly family labour and/or self-help group labour are used.

hand weeding. Furthermore they usually weed spear grass plots more than two times. This finding is in accordance with that of Chikoye *et al.* (2002), who reported that chemical control of spear grass resulted in higher benefits than hand weeding. The use of herbicides led to a better control of spear grass which in turn resulted in higher crop yields. The authors did not take the sprayer into account, which is quite expensive and beyond individual farmers' affordability unless they acquire it through farmers' groups (GV) on a credit basis or in cash. They did not consider the side effects on humans and animals nor the environmental pollution that would result from a prolonged use of herbicides. This complex background forces small-scale farmers into subsistence farming, where they perform just one weeding in the case of food crops. They argued that an additional weeding does not result in a proportional increase in crop yield due to the low soil fertility and, therefore, is not paying off. However, off-farm activities provide financial resources to meet the monetary needs of the family.

According to farmers some weeds have beneficial effects. One farmer raised the point that 'a soil without any weed is inappropriate to farming but similarly a soil that is severely infested with weeds is not a good soil either'. For example, farmers in Dannou in the Ouémé valley value *Acroceras zizanioides,* a grass weed growing in swampy areas and flood plains. They use it to control other weeds, to preserve soil moisture and improve soil fertility. Although it harbours grasshoppers, which are a serious pest in cassava, *Chromolaena odorata,* a relatively new weed, improves soil fertility and controls other weeds. Farmers' experiences with this weed species are in line with the findings of Obatolu & Agboola (1993) and Okon & Amalu (2003). Farmers also use it to cure malaria. Farmers in the village of Zouzouvou revealed that their forefathers had introduced spear grass as roofing material from the savannah zones when corrugated iron sheets were expensive. Later it became a problem to crop production due to its fast reproduction through rhizomes. However, farmers still use it in rural areas. These equivocal aspects of some weeds support the claim that the concept of a weed – a plant that is unwanted where it grows – is to some extent socially constructed.

In the production systems of the Transition Zone weed problems are not as acute as in the Southern Zone, because farmers are still practising shifting cultivation. Still, weeds constitute one of the major constraints on crop production. The most troublesome weeds inventoried are *Imperata cylindrica*, *Cyperus* spp. and *Commelina* spp. (Table 3). Weeds such as *Panicum maximum, Pennisetum pedicellatum, Andropogon gayanus* and *Rottboellia cochinchinensis* are characteristic of fallows. According to farmers, the presence of *Chromolaena odorata*, *Andropogon gayanus* and *Panicum maximum*, and of woody species such as *Mallotus oppositifolius* indicates good soil fertility. The name of *Commelina* spp. in one of the local languages is *orilèkou*, which also means 'stays until the farmer dies'. Interestingly, *Striga* spp. have not been reported to cause serious problems in the Transition Zone, although this zone falls within the distribution area of the genus. This confirms earlier reports from Gbèhounou (1998) who indicated that *Striga* spp. do not cause major problems in areas of low population density, where arable land is readily available. Also this shows that changes in agricultural practices can generate 'new' weeds.

The main constraint on weeding in the Transition Zone is also labour shortage.

Most of the children visit schools and the young people have left the village in search of employment in the cities or in neighbouring countries such as Nigeria, due to the decline in cotton prices and the collapse of the cotton sector. The disintegration of the family unit due to the desire of young people to make money has deprived the household heads from available labour for weeding. Sixty per cent of the interviewed farmers spent on average 60% of their time on weeding. However, as a rule the cotton crop is still weeded three to four times, but some cotton growers reduced their acreage and others have given up. Weeding one hectare of cotton costs 6000 F CFA (€ 9.15) to 25,000 F CFA (€ 38) depending on the composition of the weed flora, the labour availability and the degree of infestation. Using a ridging plough for weeding costs 15,000 F CFA (€ 23) per hectare. Farmers claim that an average of 14 to 20 man-days is required to weed one hectare. So weeding cotton is cheaper in the Transition Zone than in the Southern Zone. However, in rice production systems, weeding is more time-consuming and more costly. For instance, it is estimated that a young lady would spend three days to weed 400 m^2 (75 days for one hectare). Farmers reported that some weed species intermingle (crop mimicry by weeds) with rice seedlings, making weeding more difficult, tedious, stressful, and time- and money-consuming. According to farmers there is a drastic drop in crop yield if the number of weedings is reduced, and total crop failure may occur if no weeding is done at all. Ahanchédé (2000) confirmed farmers' contention and reported substantial yield losses, averaging more than 90% per cotton plant when there was no weeding at all. Except in Djidja, where cotton farmers applied herbicides, weeding is done manually.

The major weeds identified were *Striga hermonthica*, which is ranked as first constraint in 75% of the explored villages in the Northern Zones, followed by *Commelina benghalensis, Cyperus* spp. and *Ipomoea eriocarpa* (Table 3). As in the Southern Zone, the local name of *Striga* in the different local languages expresses the extent to which it constitutes a threat to crop production and people's livelihoods. For example *yiko* means 'which kills the soil', *mali* means 'which prevents plant growth', *sakara* means 'which renders sorghum plants infertile'. All these names have the same meaning: *Striga* is the enemy of crops.

Hand weeding remains the common weed management practice used by small-scale farmers. The major constraint on weeding is again labour shortage and the prohibitive cost of labour. Farmers spend 16,000 F CFA (€ 24) to weed one hectare. They usually weed cotton four times and food crops such as maize three times. This implies that a farmer spends 64,000 F CFA (€ 97.60) to weed one hectare of cotton, which is more expensive than the use of herbicides (Table 4). In Northern Benin many farmers cultivate more than 10 hectares. In this case, a farmer needs to spend 640,000 F CFA (€ 976) just on weeding. More importantly, farmers claim that it is difficult to get labourers at the peak of labour demand and that they do not have access to credit for weeding. Under these circumstances, not all farmers can weed at the right time. Consequently, farmers give priority to weeding cotton fields and abandon part of the food crops. Farmers argued that they make this choice because cotton has a market compared with food crops. Despite the collapse of cotton prices and the cotton sector crisis, farmers in the north have continued to grow cotton and weed it four times as usual. However, some farmers have reduced their acreage. Agriculture is intensified in the cotton production areas where farmers, organized in groups (GV), have access to inputs such as fertilizers and pesticides including herbicides.

Farmers' weed management strategies for the most troublesome weeds

Two major weeds deserve special attention for follow-up research and experimenting because of the damage they cause. These are *Imperata cylindrica* (spear grass) in the Southern and the Transition Zones and *Striga* spp. (witch weed) in the northern part of the Southern Zone and in areas with a warmer climate in the Northern Zones. Farmers used to dig out spear grass rhizomes but this method is difficult and time-consuming. According to farmers in Damè-Wogon, it takes a whole week for a hard-working farmer to dig out 400 m^2 or 175 man-days for one hectare, meaning that this method is feasible only for small areas. According to an African saying, 'a lazy farmer cannot reclaim a plot infested by spear grass'. As a strategy to control spear grass, farmers in the Southern Zone shifted from no tillage to ridging, a practice that both recycles nutrients and reduces weed proliferation. Experience shows that deep ridging roots out the grass' rhizomes. Planting leafy crops such as cowpea, cotton and melon (*egusi*) on the ridges covers the soil and prevents the re-growth of spear grass and restores soil fertility. Farmers prefer technologies that have multiple effects so that their practices are beneficial for weed control (e.g. cowpea, melon and cotton), for soil fertility restoration (e.g. cowpea, melon), for food availability (e.g. cowpea, melon) and / or for generating cash income (e.g. cowpea, melon and cotton).

Farmers developed a wide range of strategies for witch weed control, some leading to loss of biodiversity. Crops that are highly susceptible to witch weed have been displaced by less or non-vulnerable crops. According to farmers interviewed in Adingnigon, soil fertility decline aggravated by an erratic rainfall and severe *Striga hermonthica* infestation have led to an increased production of legumes like cowpea and groundnut and of root crops such as cassava to the detriment of maize cultivation. Carsky *et al.* (2003) reported that currently, soil fertility on the Abomey plateau is so low that only grain legumes are viable crops. In Somè, farmers shifted from millet to sorghum, as it was common to hear farmers say '*Striga* has killed all my millet'. Some farmers also attribute this change to bird damage. Farmers stopped growing late-maturing maize varieties and gave preference to early-maturing varieties of both maize and cowpea. The adoption of crop rotation and intercropping with trap crops (false hosts) are other strategies to reduce *Striga* interference. Planting crops early, at the onset of the rainy season not only helps to reduce crop yield losses caused by *Striga* but at the same time is a strategy to avoid food shortage and to bridge the 'hungry gap' before the new harvest. Transplanting of sorghum is another commonly used strategy to better manage the cropping calendar during labour peak demands and can also serve to reduce *S. hermonthica* on the Abomey plateau. In the Atacora region, transplanting sorghum is a tradition of the Otamari ethnic group. Researchers have improved it as a strategy to manage witch weed. Field observations during the diagnostic study learned that there is scope for further joint experimentation and for the development of transplanting sorghum as a weed management strategy. In the Northern Zones, where arable farming is associated with livestock production, farmers use cow dung to improve soil fertility, which in turn reduces *S. hermonthica* on cereals.

Farmers' reactions to recommended weed management practices

Farmers have insight and adaptive skills based on years of experience, and this accumulation of learning experiences may be called rural people's knowledge (Brouwers, 1993). During group and individual discussion sessions, farmers indicated which weed management strategies were widespread, which were not adopted and which were adopted to a limited extent. Table 5 presents the different weed management strategies and their level of adoption.

The discussion with scientists at INRAB revealed that weeds are considered a major constraint on crop production. The research agenda of INRAB combines soil fertility and weed problems. It seems to be a practice of formal research to consider

Table 5. Traditional versus modern weed management strategies for some noxious weed species, and their level of adoption as indicated by farmers,

Weed species	Zone where prevalent	Traditional weed management		Modern weed management	
		Methods	Level of adoption[1]	Methods	Level of adoption[1]
Imperata cylindrica	Southern production systems	Hilling and deep ploughing	+	Use of *Cajanus cajan*	+/–
		Rotation with cotton and cowpea	+	Use of cover crops (*Mucuna* spp. and *Aeschynomene histrix*)	–
				Use of *Acacia auriculiformis*	+/–
				Herbicides	–
Striga hermonthica and *S. gesnerioides*	Abomey plateau and northern production systems	Rotation with groundnut and cowpea	+	Rotation with legumes	+
				Use of herbaceous legume cover crops (*Mucuna* spp.)	–
		Crop associations (cereal–legume)	+		
		Pulling out before flowering	+/–	Use of tolerant varieties (maize and cowpea)	+/–
		Transplanting (sorghum seedlings)	+	Inorganic fertilizer	+
		Use of cow dung	+/–		
Commelina benghalensis	All production systems	Uprooting and removal of roots	+	Herbicides	–

1 – = not adopted; +/– = more or less adopted; + = adopted.

weed problems as subordinate to soil fertility problems. However, this pre-analytical choice (Röling *et al.*, 2004) may need closer scrutiny. In terms of effects on farming (e.g. lower yields, additional time spent on management, effects of labour availability, opportunities for the development of Farmer Field School curricula), weed problems could also have been described as a manifestation of pest problems. Possibly as a consequence of subordinating weed problems to soil fertility problems, few research recommendations were brought to farmers. For example, a research project at INRAB undertook a participatory evaluation of soil fertility management technologies with farmers in the Couffo department including the use of the green manure and cover crop *Mucuna pruriens* var. *utilis*. After experimenting with *Mucuna* for two years to restore soil fertility, farmers discovered that this aggressive cover crop is effective in suppressing weeds, especially spear grass, which is a problem on the Adja plateau (Brouwers, 1993; Versteeg & Koudokpon, 1993; Daane *et al.*, 1997; Vissoh *et al.*, 1997; 1998; Manyong *et al.*, 1999). So the adoption of *Mucuna* is because of its effectiveness in eradicating spear grass, and not so much because of its ability to restore soil fertility, as the scientists had initially intended. The dynamic and innovative character of farmers has changed researchers' objectives and made them adapt their own realities (Douthwaite *et al.*, 2002).

Consequently, extension agents and NGOs provided incentives for the dissemination of the *Mucuna* technology, which researchers thought would improve soil fertility and suppress weeds. The adoption of these technologies is constrained by a number of factors of which the major one is that the *Mucuna* species that were brought to the farmers are not edible. All the farmers interviewed mentioned that most of the cover crops in general and *Mucuna* spp. (*M. pruriens* var. *utilis, M. pruriens* var. *cochinchinensis, M. rajada*, etc.) and *Aeschynomene histrix* in particular, are crops of long duration that occupy the land and prevent the farmers from cropping during the second rainy season. They are not willing to devote their meagre resources to a crop that gives no immediate return. In addition, in the Transition Zone, farmers revealed that it is difficult to incorporate *Mucuna*'s biomass into the soil with their hand tools. Furthermore, as *Mucuna* adopters use it discontinuously, *Mucuna* seeds are no longer easily available since SG2000 withdrew its support as they easily loose their viability from one year to the other. This failure of *Mucuna* and other leguminous cover crops indicates that technology adoption has to do with the technique having to fit in with the farmers' biophysical environment and with the socio-economic environment (see also Nederlof & Dangbégnon, in preparation). Likewise, the woody legume *Acacia auriculiformis* was recommended to farmers for suppressing spear grass, but farmers rather plant it to produce firewood, as their environment is completely deforested.

As for herbicides, apart from two farmers who had tested them, we found no one among the interviewed farmers who used them due to their prohibitive costs. As an index of non-adoption, a young farmer in Niarosson village (Atacora region) even expressed the fear that their utilization would prevent weeds from protecting the soil surface and produce soil organic matter. However, interviews held with input suppliers and distributors' institutions revealed that the GVs in the Northern Zone use herbicides for cash crops like cotton and also for maize (Coopérative d'Approvisionnement et de Gestion des Intrants Agricoles – CAGIA, personal communication). Data obtained from input dealers indicated that in 2003 on about 16% of the cotton area herbicides had been used against 2% in 1995. Herbicides are also used in food crops: in 2003, herbicides had been used on more than 23,000 hectares of maize and 1500 hectares of rice (CAGIA, personal communication). But according to the farmers interviewed, an individual small-scale farmer cannot afford to apply herbicides, reason why they emphasize lack of credit and low prices of commodities as major constraints. The GVs use herbicides on a credit basis. Some farmers complained, because despite the application of herbicides they had to engage in complementary weeding twice.

Maize and cowpea varieties tolerant of *Striga hermonthica* and *S. gesnerioides* were recommended to farmers but the constraint that limits their adoption is the non-availability of seeds. In Somè village, farmers do not crop maize on the degraded, unfertile and infested soils. They grow legumes and sorghum for which they do not use fertilizers. Maize is grown on plots not severely infested, which are located at some distance from the village. But farmers do not use fertilizer there either. The lesson learnt is that a technology, no matter how effective it is from a purely technical perspective, must fit in with farmers' cropping systems and socio-economic conditions to have a chance to be adopted.

The conceived vicious circle of weed problems based on farmers' perceptions (Figure 2) still persists in spite of research recommendations. The explanation of this circle is that changes in productivity of the land due to soil fertility decline may relate to emerging weed problems. This in turn may increase the need for labour, while actually there is less labour available and farmers do not have enough money to hire labourers because market prices are too low, farmers have no market control over prices, and governments prefer cheap import over locally produced food. To break this circle, the following options are envisaged: (1) provide credit to farmers, or (2) improve their knowledge to allow them to manage weeds efficiently at a lower cost. However,

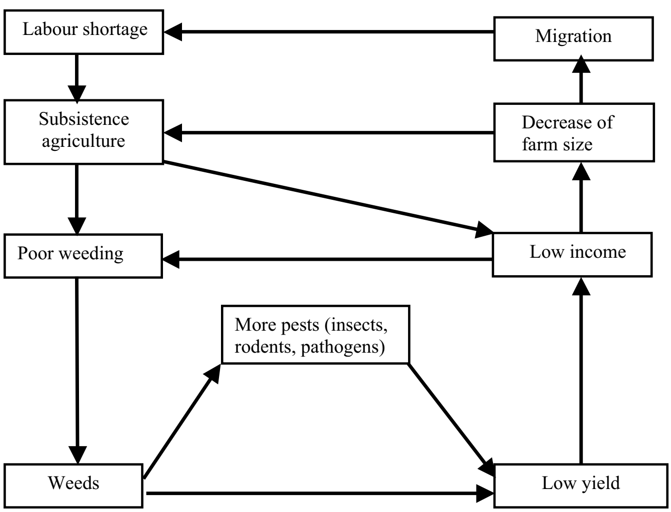

Figure 2. The vicious weed circle.

the prices farmers receive for agricultural products are so low that they cannot afford to buy inputs. In that case, the credit option is a dangerous strategy because the price is insufficient to repay the debt. Moreover, apart from low and unattractive prices, cotton growers complained about the poor quality of supplied inputs (fertilizers and pesticides) that led to low cotton yields and to farmers running into debt. As for the option of improving farmers' knowledge, research does not seem to have the answers as the few solutions developed are hindered in being adopted by farmers (e.g. the case of *Mucuna* technology). So it is worthwhile to try and work closely with farmers to see whether technologies can be developed that are effective locally and acceptable to farmers.

Follow-up to the diagnostic study

The feedback and the validation of the results of the diagnostic study with farmers in Somè and Damè-Wogon on the witch weed and spear grass case studies, respectively, led to the formation of farmer groups for carrying out the subsequent experimentation phase. In Somè, farmers seem to have lost confidence in themselves to find effective and acceptable solutions to witch weed problems and are still expecting miraculous solutions from researchers. Together with the farmers we made a contract to search for solutions that work and are acceptable through joint experimentation and discovery learning. The volunteer farmers confronted with witch weed problems and willing to get effective and acceptable solutions formed a group for the experimental phase of this study. In Somè, two different farmer groups were formed, one in each of the largest hamlets that compose the village. However, the groups have agreed to meet during field visits to exchange experiences and learn from each other. In Damè-Wogon farmers decided that the two different farmer groups that participated in the cowpea project (Projet Niébé) form a group for the joint experiment and discovery learning. These farmers were selected from the five villages that compose the sub-district of Damè-Wogon, assuming that the developed technologies can diffuse into each of these villages. The selected farmers are either leaders of the GV, GF, the local rural credit bank Caisse Rurale d'Epargne et de Prêt or members of one of these farmer organizations. Farmers in Damè-Wogon accepted to test an integrated strategy for spear grass management, including deep ridging and a rotation of cowpea and maize. In Somè, farmers agreed to test, as control measures against witch weed, transplanting of sorghum, rotation with maize and intercropping with legumes (cowpea, soya bean, groundnut) and the use of tolerant maize varieties. Such joint experimentation and testing are currently under way and could lead to the development of curricula components for Farmer Field Schools (FFS). According to the International Potato Center and Users' Perspectives with Agricultural Research and Development (Pretty, 2002; Anon., 2003b), FFS are a form of social learning, negotiation and effective collective action that focuses on society's relationship with nature. FFS can be regarded as a training method based on learning-by-doing (Van De Fliert, 1993 (in: Bruin & Meerman, 2001); Röling, 2002) that allows farmers to make their own observations, draw their own conclusions and make their own decisions (Röling, 2002). Furthermore, FFS is an explicit expression of beta/gamma perspective. It has to do with the interface between a community and natural resources, i.e., land use (Röling, 2002). The format of the FFS could be used after being thoroughly adapted to local needs and augmented with components of locally adapted technology development (Bruin & Meerman, 2001). This means that FFS must not only develop systems that work, but above all systems that are acceptable and desired by farmers. In other words, farmers must know it, want it, and be able to do it (Röling, 2002). Röling observed that FFS could become a method for empowering small farmers that is not rooted in some technical concern. Empowerment means that people, especially poorer people, are able to take more control over their lives and secure a better livelihood with ownership and control of productive assets as a key element (Chambers, 1993).

Critical reflection on the diagnostic study

The technographic studies played an essential role in the pre-analytical choice of weed problems as they showed that farmers expressed an urgent need for innovations for weed management despite existing indigenous knowledge and few technical recommendations. This implies that the existing weed management strategies are not effective in efficiently managing troublesome and parasitic weeds. So these technologies need to be improved, adapted to fit in with farmers' needs considering the actual context (economy, market conditions, ecological conditions, ethnic diversity, wealth differences in the community, etc.). If the technographic study is a new concept, diagnostic studies are not, but what seems different is how farmers are effectively involved in the identification of constraints and opportunities. How is local knowledge taken into consideration in the definition, design, implementation and evaluation with an active participation of the beneficiaries of agricultural research? The diagnostic studies are meant to bridge this gap and allow researchers together with beneficiaries of research results to set a common research agenda in a complementary way.

The choice to work on weed problems was a pre-analytical choice as it was made before the start of the diagnostic study. Reasons for making this choice included both professional and personal experience by the first author. Another reason was that the agenda of formal research often subordinates weed problems to soil fertility problems, thereby disregarding the different effects weed problems have on an issue like labour availability. Another pre-analytical choice was to execute the diagnostic study in villages that have experienced previous interactions with formal science. The methodology used in the diagnostic study was somewhat influenced by the methodology used by the cowpea project (Projet Niébé) in Benin (Kossou *et al.*, 2001), viz. participatory rural appraisal methods, such as structured, semi-structured and unstructured interviews, transect studies and field visits with participant observations. Contacts with the communities were made through the extension services and the GV. The Beninese Ministry of Agriculture, Livestock and Fishing (MAEP) through its extension services has organized farmers in groups (GVs) to allow them to have access to the production resources, mainly inputs and credit. In retrospect, we may wonder whether it would not have been better to directly contact communities. If extension agents had not been fully trusted by farmers, a risk of collecting biased data would have occurred. Lack of trust of (government-paid) extension agents may have become manifest now that presently the cotton sector is in crisis due to the supply of inputs of poor quality, low cotton prices, and the non-payment of cotton premiums to farmers. We should also ask whether farmers would trust a researcher they have never met before. This is an essential question and what matters is how a researcher collects data by combining many sources of information (triangulation) as to get reliable and trustworthy data. Such methodological pluralism entails the use of more than one method of qualitative enquiry, and combines qualitative and quantitative methods to provide complementary information (Moris & Copestake, 1993). An assessment of the implications of having made the choice of weed problems before speaking to a single farmer might have somewhat influenced the way the diagnostic study was conducted, including the questions asked to collect information. Visiting a large number of villages during the diagnostic phase enabled us to obtain an overview of the weed problems as perceived by farmers. However, the main drawback was that it did not allow deepening information collected due to time and resource constraints. So a lesson to be learnt for future diagnostic studies is to sample a manageable number of villages per agro-ecological zone in order to carry out an in-depth study to have a thorough and contextual understanding of the production systems before setting the research agenda with farmers. However, an in-depth study, including joint experimentation, will be conducted in the selected villages (Somè and Damè-Wogon) (Figure 1) to deepen the data collected during the diagnostic study.

Conclusions

This participatory diagnostic study clearly showed that farmers in Benin perceive weeds and lack of appropriate weed management strategies as major constraints on crop production and that population pressure on available and insufficient arable land aggravates the problems. Uncertain land tenure systems, lack of labour and credit, and low agricultural product prices constitute further major bottlenecks for effective weed management. The study provided the evidence for a paradigm shift in technology development in general and weed management in particular to enable farmers adopt acceptable and feasible technologies. Unlike past research and extension approaches (e.g. top-down model) that consisted of developing technologies and recommending them to beneficiaries without their active involvement, contracts were made with farmers to interactively and institutionally develop weed management strategies that are socially acceptable, effective and feasible in small-scale farmers' conditions with indigenous knowledge as a starting point. On the whole, this article shows that a participatory diagnostic study is an essential phase in the development of innovations. The study provided farmers with an opportunity to share their perceptions and experiences on research and development issues and to voice their expectations based on their living conditions in such a way that an agreed-upon research agenda was set between them and researchers and developers. It was also an occasion for farmers to show their willingness to participate in joint experiments and contribute to develop technologies that work and are acceptable in order to acquaint themselves with the research process.

The next step aims at designing an interactive research process that will involve a group of farmers elected by and acting on behalf of their community to improve on the above mentioned weed management technologies through learning by doing and empowerment. The improvement and scaling up of these selected weed management strategies are also envisaged during and at the end of the research process owing to the democratization process of science whereby farmers and researchers will engage in weed management technology development on an equal and complementary basis.

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