Participatory development of weed management technologies in Benin

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Dit onderzoek is uitgevoerd binnen de onderzoekschool: CERES, Research School for Resource Studies for Development

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Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van Wageningen Universiteit,
Prof. Dr. M.J.Kropff
in het openbaar te verdedigen
op vrijdag 20 oktober 2006
des morgens te 9:00 uur in de
ILACI Salle de Conférence, Université d'Abomey-Calavi, Bénin

Pierre V. Vissoh (2006)

Participatory development of weed management technologies in Benin.

PhD Thesis Wageningen University, Wageningen, The Netherlands.
With ref. – With summaries in English, Dutch and French.
ISBN 90-8504-434-0

Propositions

1. Weed science provides necessary but not sufficient knowledge for effectively dealing with speargrass and *Striga* sp. (This thesis).

2. The emergence of novel herbaceous weeds is both a cause for and a consequence of the impoverishment of rural people in West Africa (This thesis).

3. In the Republic of Benin, most intellectuals have lived, at least during their childhood, in thatched houses, made of shoots of speargrass (*Imperata cylindrica*). This awareness should help them to realise that weeds are socially constructed.

4. Local dynamics may under very unfortunate biophysical and socio-economic conditions (as in Somè central) be insufficient for development. The creation of artificial conditions may be a prerequisite to open the windows of opportunity, without which the local cradle cannot be heard (this thesis, in reaction to Hounkonnou, 2002).

5. It is more important for scientists and extensionists to deconstruct their own assumptions and the theories that inform their work while engaging in experiential learning with farmers, than to carry out interdisciplinary research.

6. The (increasingly) erratic nature of rainfall in southern Benin will make the test of even the most effective and acceptable technology a gambling game (G. Vigan, late chief of Somè village).

P. V. Vissoh
Participatory development of weed management technologies in Benin
Abomey-Calavi, 20 October 2006

Abstract

Vissoh, P.V. 2006. Participatory development of weed management technologies in Benin. Ph.D thesis, Wageningen University, Wageningen, The Netherlands, 187 pp.with English, French and Dutch summaries.

Weeds constitute a major constraint to agricultural production in the Republic of Benin. Agricultural intensification and the evolution towards permanent cropping systems have led to the emergence of novel weed problems. A diagnostic study identified speargrass (*Imperata cylindrica*) and the parasitic weed *Striga* spp. as major novel weeds. Both weeds are difficult to eradicate, cause substantial food crop losses and exacerbate rural poverty through crop failure, higher labour inputs, rising costs of production and reduced availability of suitable land. Different actors reacted differently to the weed problem, in terms of the construction of knowledge, labour practices and technology development. Farmers have actively engaged in technology development and new labour practices have emerged. Researchers have not translated the new weed problem into a research priority until recently. As a consequence, inappropriate weed management technologies were proposed, and these showed low adoption. As part of the Convergence of Sciences (CoS) programme, this study attempted through a multiple stakeholder approach, using discovery learning and joint experimentation, to enable farmers to co-develop and use low-cost technologies that are effective and acceptable. The joint learning enabled farmers to better understand the biology of these weeds as a basis for choosing appropriate measures. An integrated strategy, which included deep ridging, deep hoe-weeding and shading by legumes, was more effective in suppressing speargrass than farmers' practices. While this new strategy also improved soil organic matter and nitrogen to a subsequent maize crop, farmers' need to bridge the hungry gap forced them to trade off legume grain production against speargrass suppression and subsequent maize yield. Farmers are also constrained by labour shortage and the lack of credit. Given their small windows of opportunity, farmers can only gradually reclaim land that is infested by speargrass. Early planting, sorghum transplanting, crop rotation and intercropping, and trap cropping were partly effective in increasing cereal and cowpea yield and in reducing *Striga hermonthica* and *S. gesnerioides*. However, these improved practices made also clear that the *Striga* problem can only be addressed within an integrated crop and soil fertility management strategy. Improved weed management can be best achieved through a Farmer Field School to empower small-scale farmers to be self-reliant in finding their own solutions. Farmer self-assessment indicated that the CoS approach contributed to their increased human and social capital assets, which are a prerequisite for raising their livelihoods. The CoS approach, as applied in this study, is critically reflected upon and recommendations are made for the next phase.

Keywords: permanent land use, weeds, indigenous knowledge, integrated crop and soil management, participatory learning, co-research

Preface

My dream to build on farmers' knowledge dated back from when as a fresh Ingénieur Agronome, I joined a R&D team at the headquarters of the CARDER Atlantique in 1989. I realised that most research recommendations were only partially or not at all used by the small-scale farmers. The members of the research team thought that in order to increase the rate of adoption of the recommended technologies, it would be necessary to build on farmers' own practices. I had become strongly convinced of this idea by the time that I completed my Masters programme, after carrying out my fieldwork in 1993 in the three former southern departments (Atlantique, Mono and Ouémé) of Benin. Subsequently, from my experiences of working with the Sasakawa Global 2000 project, I drew the conclusion that technologies developed by scientists should take into consideration both biological and socio-economic aspects in order to increase their chance of acceptability at farm level. At this time I submitted a PhD research proposal to the University of Reading (UK), which was accepted, but because of a lack of funding, I could not benefit from this opportunity.

My dream none the less has become a reality through the Convergence of Sciences (CoS) programme, funded through the International Research and Education Fund (INREF), Wageningen University, The Netherlands, and by the Directorate General of International Cooperation (DGIS), Ministry of Foreign Affairs, the Netherlands, for which I would like to express my deepest gratitude. My sincere thanks go to the brains trust who conceived this programme, especially to the general coordinator Prof. Dr. Ir. Arnold van Huis for this initiative and his intellectual rigour.

I am appreciative also of the scientific coordination committee, composed of Prof. Dr. Ir. Niels Röling, Dr. Dominique Hounkonnou and Prof. Dr. Ir. Arnold van Huis, for their commitment throughout the completion of the first phase of this programme. I here acknowledge in addition the contributions of the national coordinators in Benin and Ghana, respectively Prof. Dr. Ir. Dansou K. Kossou and Dr. O. Sakyi-Dawson.

Interdisciplinary work is never the sole effort of the author and this study is no exception. I wish to thank especially the promotors, the CoS working group, farmer colleagues, friends, and my nuclear family, all of whom have contributed in one way or the other to the completion of this thesis.

I acknowledge above all the invaluable support and contribution of my supervisors, without whom this study would not have been completed. I am indebted to Prof. Dr. Ir. Niels Röling, who at first doubted if working on weeds was opportune and worthwhile but who became convinced by my early results and thereafter showed enthusiasm, faith, trust, support, and scientific rigour, and who contributed substantially to the development of this thesis. I also owe

Prof. Dr. Thom W. Kuyper for his close supervision, his scientific criticism, his perfectionism and his constructive input, without which this work would not have been approved. I am heartily sensible of his extensive comments, recommendations, contribution and the considerable time he has devoted to shaping this thesis. Special thanks go to Prof. Dr. Paul Richards who in fact was the one who triggered the idea of addressing the current pressing weed problems when I presented to him my initial proposal in Wageningen. My thanks go also to Prof. Dr. Janice Jiggins, who contributed to the self assessment of the learning process (Chapter 7), and who suggested involving farmers' groups in a sustainable livelihoods study. I am grateful to Prof. Dr. Ir. Cees Leeuwis for his contribution at the early stage of proposal writing and for providing me with relevant literature, and to Prof. Dr. Ir. Paul Struik and Prof. Dr. Ken Giller for their critical comments during the implementation phase and field visits.

Ce travail est le fruit d'une collaboration interuniversitaire. L'équipe de supervision au Bénin a eu une grande part de responsabilité dont elle s'est acquittée avec succès. Je saisis cette occasion pour témoigner ma profonde gratitude au Prof. Dr. Ir. Dansou K. Kossou, coordonnateur national pour toutes ses sollicitudes malgré ses multiples occupations.

Au Dr. Ir. Gualbert Gbèhounou, je ne sais exactement comment le remercier pour sa constante sollicitude, sa rigueur, sa probité scientifique et sa contribution combien inestimable pour sortir cette thèse des sentiers battus. Je reste sensible pour sa supervision rigoureuse malgré notre amitié. Je veux de tout mon cœur le remercier sincèrement et lui demander s'il a souvenance de la nuit partagée ensemble à la station de recherche d'Ina alors que nous rentrions de différentes missions pour nos institutions respectives. J'ai encore vivant à l'esprit les sujets d'ordre scientifique que nous avions échangés et qui ont abouti à l'obtention d'un exemplaire de votre thèse sur le *Striga*. C'est dire que l'engouement que j'ai eu à travailler sur ce parasite et les premières notions sont à votre actif. Vous n'avez jamais douté un seul instant de mes capacités à faire cette étude. Je vous en remercie infiniment.

Au Prof. Dr. Ir. Adam Ahanchédé, je loue votre rigueur pour le travail bien fait, vos conseils, recommandations ainsi que votre contribution dans l'aboutissement heureux de ce travail. Au Prof. Valentin Agbo, vos conseils ne m'ont pas fait défaut malgré vos multiples sollicitudes. Soyez-en remercier. Je témoigne aussi ma profonde gratitude Au Dr. Roch Mongbo, pour ses idées fécondes d'anthropologue et de sociologue qui ont enrichi ce travail. Je ne saurais passer sous silence les contributions non négligeables des Dr. Ir. Rigobert Tossou et Simplice Vodouhè. J'apprécie les facilités dont j'ai bénéficiées au niveau du laboratoire de sol du Dr. Guillaume Amadji et les contribitions des Professeurs Nago Maturin et Ambaliou Sanni.

A vous Dr. Dominique Hounkonnou, vous êtes pour moi un modèle et une source d'inspiration. Vos conseils, suggestions et recommandations et votre ardent désir de me voir réaliser ce parchemin ont été pour moi la principale source de motivation. Vous n'avez ménagé aucun effort pour ma réussite. Le Prof. Dr. Ir. Nestor Aho qui m'a donné le goût de la recherche, reste pour moi un enseignant éducateur toujours soucieux de mes réussites académiques et professionnelles. Ses conseils et son soutien moral ne m'ont jamais fait défaut surtout pendant mes moments difficiles. Qu'il reçoive mes sentiments de profonde gratitude.

J'apprécie à leurs justes valeurs l'engouement, l'enthousiasme et les capacités d'initiative des producteurs de Damè-Wogon, et de Somè de qui j'ai beaucoup appris sur les systèmes de culture et singulièrement sur la gestion intégrée des sols, des cultures et des mauvaises herbes et surtout à faire de la recherche participative. Je remercie particulièrement Elie Kounou pour son rôle de facilitateur et son hospitalité. Je reste persuadé qu'ils feront bon usage de ce que nous avons construit ensemble et les assure de ma volonté indéfectible de les aider à consolider ces acquis dès que d'autres opportunités se présenteront.

J'exprime ma sincère reconnaissance à Flauberte Koulony, secrétaire de Convergence des Sciences au Bénin pour ses sollicitudes et son soutien moral. Je remercie les assistants de recherche Kintonnou Athanase, Tamègnon Rémi et Loukpé Cyrille, Olivier Flatin et Hector Kpangon pour m'avoir aidé dans la collecte des données. Je n'oublie pas les contributions louables de Dr. Alexis Onzo, Mr. Théophile Odjo pour les analyses statistiques et deRéné Tokannou et de Ramanou Fassassi pour leur soutien. Je reste reconnaissant à l'endroit de Grégoire Houngnibo, représentant de l'IFDC-Bénin et de son personnel pour m'avoir accordé des facilités d'études dans leur institution.

Je reste redevable à mon épouse Cécile et nos enfants pour qui mes absences répétées aussi bien à l'intérieur qu'à l'extérieur ont coûté des sacrifices moraux et financiers énormes. Je les remercie pour leur patience, courage et leur sentiment d'avoir été abandonnés. Dr. Séraphin Vissoh et Dr Justin Tossou, ainsi que mes frères et sœurs sont remerciés pour leur sollicitudes et soutien moral. Aux amis, parents et collègues dont j'ai tu les noms ici mais qui d'une manière ou d'une autre ont contribué à la réalisation de ce travail je vous prie de recevoir ma profonde gratitude.

Many thanks, finally, to Mrs Marthy Boudewijn, secretary of CoS programme, Wageningen, for being enthusiastic and cooperative throughout this study. I am grateful to my colleagues Antonio Sinzogan, Afio Zannou, Aliou Saidou, Suzanne Nederlof, Samuel Adjei Nsiah, Emmanuel Dormon, Comfort Kudadjie and Godwin Ayenor for being cooperative. Special thanks go to Alberton Odair and Nina Fatouros for helping in the lay out of this thesis.

I believe that the results of this study will be useful for many of the small-scale farmers struggling to combat weeds in Benin and - why not – also in other parts of sub-Saharan Africa. This work is dedicated to them.

Pierre V. Vissoh — Abomey-Calavi, October 2006

Contents

Chapter 1

General introduction

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General introduction

Background

Weeds refer to plants that grow at a place where man does not want them (van Rijn, 2000). This concept of weeds originated with humans within the context of their production needs. Although weeds have many undesirable features, some weeds at the same time are valued by humans. These useful aspects render the concept of weed more complex. In fact the difficulty of finding one satisfactory definition of 'weed' is insuperable since this word has to be defined (1) in the ecological sense: a plant that grows spontaneously in environments modified by men; (2) in the weed-science sense: unwanted plant (Godinho, 1984).

My experience with weed problems started when I was a young boy, helping my late father in the family farm located in the district of Savalou, in the Transitional Zone of Benin where population density was low and land availability still sufficient. He spent six days per week on his farm and took a rest on Sunday. He devoted most of his time to weeding his farm apart from sowing and harvesting of crops for which he usually hired workers. I remember that it was difficult for him to get workers at the right time during seasonal labour peak demand periods because every young farmer needed to crop his field before offering his service to others. Workers and sometimes self-help group of his son-in-law prepared land and ridged plots where he grew maize, yam, cassava, cowpea, egoussi (melon), groundnut, and cotton. Seasonally, he hired migrants from the Abomey plateau or from the Atacora region for ploughing and hilling activities and sometimes for weeding. They were lodged, fed and paid for their daily work. My father has sent all his sons to school and the daughters helped our mothers in their fields except when he needed help for sowing and harvesting. During holidays, he usually relied on his sons' labour and we had to weed all day long without any break apart from the short time allowed for taking breakfast and/or lunch. Weeding was stressful and time-consuming, as the first weeded plots were re-infested when the last plots were weeded. My father did not allow his sons to weed a plot severely infested by speargrass (*Imperata cylindrica*). He did not want us to injure our hands, legs, and eyes and end up with an itching body. He usually hand-pulled it out himself as labourers would just hoe superficially and the plot would be re-infested within a week. It is worth stressing that at that time speargrass invasion was not as severe as it is presently because the prevailing cropping system was shifting cultivation and there was plenty of arable land. Every year new plots were opened for yam and cotton cultivation and plots cropped for three to four years were abandoned for long-term fallowing, not because their fertility was exhausted but because the frequency of weeding had to be increased. Sometimes these plots were given to his wives (our mothers) on request for one or two years depending on the level of weed infestation before fallowing. Labour availability particularly labour for weeding determined the size of the farm. Remote plots were abandoned forever when he got older. I cannot even locate all the plots he cultivated when he was physically active nor estimate land he owned. Part of these lands has now been taken by other farmers.

What was most painful in weeding was the backache we felt and we were hard to wake the following day. Weeding for me was debasing and disgraceful. The stress related to farm activity in general, and weeding in particular, compelled me to resign from helping my father during holidays and to work harder at school to complete my education.

This childhood experience with weeds enabled me to get insight into weed problems after completing my certificate of 'Ingénieur Agronome' when I was involved in a Research and Development (R&D) team called 'ESYCTRA' (study of traditional cropping systems) from 1989 to 1991 at the 'Centre d'Action Regional pour le Développement Rural' (CARDER). So many years later, I learned that weeds still remained a constraint to the take off of agricultural development of small-scale farmers. Weed invasion was more severe in densely populated areas where land was more or less permanently under cultivation (Vissoh *et al.*, 2004). Farmers had to spend an increased percentage of their time and resources on weeding or had to adapt their cultural practices. For instance instead of increasing the number of weeding, they reduced it when additional weeding was not paying off due to low agricultural prices. In the areas where a decline in soil organic matter was coupled with weed invasion, farmers shifted from no tillage to ridging. However, this practice, which was imported from the Zou department, was executed badly (Floquet & Mongbo, 1994). Alley cropping with woody legume species (*Leucaena leucocephala* and *Gliricidia sepium*) was introduced in southern Benin in response to the combination of low soil fertility and weed problems (Kang *et al.*, 1989). This supposed economically beneficial technology did not yield the expected results at farm level because it was constrained by land scarcity and increased labour demand required for pruning hedgerows (Douthwaite *et al.*, 2002; IITA, 2002; Vissoh, 1994).

From 1991 to 2001 I worked as an extension agent and resource person linking the Sasakawa Global 2000 (SG2000) project to research institutions. SG2000 recommended a technological package for maize cropping. This package included two compulsory weedings (one weeding just after the application of a basal dressing of NPK fifteen days after planting and the second weeding just before urea application). Farmers were advised to concentrate their effort on the production test plots (half a hectare) to prevent yield losses due to weed invasion in order to reimburse the loan they were provided with. The project did not provide them with credit but attempted to introduce the use of herbicides. Unfortunately, their non-availability and prohibitive cost discouraged farmers. SG2000 also embarked on a nation-wide dissemination of mucuna (*Mucuna pruriens*) to restore soil fertility and reclaim land infested by weeds (Galiba *et al.*, 1998; Tarawali *et al.*, 1999; Vissoh, 1994; Vissoh *et al.*, 1997, 1998). The idea of coupling soil fertility with weed suppression was triggered by experimenting farmers when they discovered that the introduced mucuna could help reclaim abandoned land (Douthwaithe *et al.*, 2002; Versteeg & Koudokpon, 1990). However, recent studies on the use of mucuna in southern Benin showed a decreasing trend. Schulz *et al.* (2003a) reported that the area planted to the crop in Benin had dropped by around 30% between 1996 and 1997 while Honlonkou *et al.* (1999) indicated that 93 % of the farmers in southern Benin had chosen not to adopt mucuna. These data show that farmers have abandoned the use of this legume due to the fact that it is not adapted to the socio-economic conditions of small-scale farmers (Nederlof & Dangbégnon, 2006).

SG2000 in conjunction with the World Phosphate Institute (IMPHOS) conducted a three-year on-farm trial (1996-1998) on the response of maize to triple super phosphate (TSP) in the different agro-ecological zones of Benin. Farmers' participation was just limited to providing land and service, a form of participation that Biggs (1989) termed contract participation. The demonstration approach used was a pure 'top-down' system backed-up by the following philosophy: 'what farmers hear they rarely believe; what they see on somebody else's plot, they can doubt; but what they do themselves, they cannot deny' (Galiba, 1994; Galiba *et al.*, 1998).

Societal problems posed by weeds

Agricultural intensification is a major driver towards more permanent land use systems. Shorter fallow periods cause the emergence of new weeds and this novel weed problem then becomes a subsequent cause for further intensification towards permanent land use. In general, external inputs (e.g., improved seeds, fertilisers and herbicides) then become increasingly important to boost agricultural production. However, resource-poor farmers face a number of constraints including (1) lack of fertilisers and herbicides, or prohibitive cost when they are available, (2) increasing labour shortage and labour cost due to schooling and migration of physically active people, (3) increased population pressure further driving to permanent land use and (4) ever greater weed pressure together with soil fertility decline. Climatic change (changes in rainfall pattern, or changes in rainfall use efficiency by crops, cf. Hein & De Ridder, 2006) could possibly be added to this list of constraints. These constraints force farmers to subsistence agriculture. Low agricultural prices and low investment in agricultural production (and weed management in particular) keep them in a vicious cycle of poverty.

One of the principal drivers behind this vicious cycle of poverty is low agricultural profitability according to the Forum for Agricultural Research in Africa (FARA, 2004). To break this vicious cycle and improve livelihoods as required to meet the Millennium Development Goals, the challenge set in the New Partnership for Africa's Development's (NEPAD) comprehensive Africa Agriculture Development Programme (CAADP) is to increase agricultural output by 6% per year for the next 20 years. This requires an annual 3% growth in total productivity, which is a major challenge (FARA, 2004). This challenge is not only technical. Low prices for farm products, no capacity to hire labour or buy inputs, and low yields are part of the problem. The challenge for agricultural research is to help farmers break this vicious cycle and to enable them to adopt permanent cropping systems that work under farmers' conditions and are acceptable to them.

Research problems posed by weeds

Past agricultural research approaches had a limited impact on the livelihoods of small-scale farmers. In order to increase research impact on agricultural development, the Convergence of Sciences (CoS) programme suggested that agricultural research be embedded not only in participatory processes, but also explore the interface between bottom-up and top-down process, and be demand-driven and client-oriented. In other words, CoS should work on the principle that innovations emerge as a property of interaction among different stakeholders in agricultural development (Hounkonnou *et al.*, 2006). In agreement with the philosophy of the CoS programme, of which this dissertation is part, the work reported in this dissertation combined social and biological sciences, and farmers' local knowledge and formal science (Van Huis *et al.*, 2006).

Farmers' participation in the research pathway is paramount to develop or build on existing strategies that work and are desired. This approach requires experimentation with participatory learning and action. First, research could explore the problem by carrying out a diagnostic study in the field; second, analyse how the phenomenon was and is perceived by different actors; third, work closely with farmers who have been innovative and dynamic in coping with these new challenges to see whether a combination of scientific and farmers' knowledge can lead to results that work in the local circumstances. These different steps entail the blending of biological and social sciences (*Beta* and *Gamma* interaction: Röling, 2000) and the integration of indigenous knowledge and modern science in an iterative process. According to Leeuwis & Van den Ban (2004) innovations have technical and social dimensions, which are closely connected in the sense that both provide space and limitations to the other. A viable research methodology is no more an experiment in which hypotheses are tested, but a new way of looking at agricultural research which is beginning to emerge in various international networks (Lee, 2002). By his way, research can empower farmers to be self-reliant in improving the management of their cropping systems including weeds.

Study area

Benin is a West African country located in the gulf of Benin. Its total area is 112,620 km^2. Its population is about 7,460,025 inhabitants (INSAE, 2003). Agriculture is the main activity, which occupies about 75% of the active population and contributes 40% to the gross domestic product (GDP). After the diagnostic study I selected two representative villages where two weeds (speargrass and striga [*Striga* spp.]) were identified as one of the major agricultural constraints. Both villages are located in the Southern agro-ecological Zone of Benin.

Damè-Wogon is situated in the district of Bonou (Ouémé department). Located in the southeast, Bonou district covers a total area of 275 square kilometres and its ethnically homogeneous population was estimated at 29,656 inhabitants. Different toposequences comprise a bottom valley made up of hydromorphic and sandy alluvial soils and the plateau where the soils are ferralitic. The natural vegetation was replaced by natural and planted palm oil trees on the plateau. Some relic forests remain. Permanent cultivated plots are severely infested by speargrass. Somè is situated in the district of Za-Kpota (Zou department), located in the central part of Benin on a plateau of 200 to 300m altitude. Its population is homogeneous and is estimated at 87076 inhabitants. Soils are ferralitic with low inherent fertility. The natural vegetation is completely replaced by palm oil plantations and fields with annual food crops. Fields are severely infested with *Striga* species. Due to population pressure there is an acute land shortage that forces young people to migrate.

Purpose of the research

Weeds are a component of the more complex problem of soil fertility decline. Therefore, it is difficult to study weed problems in isolation. Developed soil fertility and weed management technologies (e.g., fertilisers, herbicides, improved seeds, etc.) are out of reach for small-scale farmers due to unaffordable investment costs and low market prices for agricultural produce. Moreover, most of research recommendations (e.g., green legume cover crops) are labour-intensive.

However, these constraints should not be interpreted as a claim that Beninese farmers are static and lack resilience. Farmers are usually innovative and try to counter problems of soil fertility decline (Giller *et al.*, 2006). But strong external globalising forces make it imperative to opt for technologies that are feasible in the present circumstances. In this regard, it is important that experiments carried out did not create artificial technical or economic conditions. The experiments sought to build upon existing cropping systems that evolve towards permanent land use systems. Such permanent land use systems have not been developed yet. It is then worth to use a holistic approach through which farmers' windows of opportunity are explored to strengthen their decision-making capability. The main objective of the study is ultimately to improve small-scale farmers' production systems for enhancing their livelihoods. This was achieved through interactive learning of integrated crop and weed management. The specific objectives were to:

- Explore the importance of weeds in the farming systems and analyse how different categories of actors (farmers and researchers) constructed weeds;
- Design a learning mechanism to ensure participatory weed and crop management in order to empower farmers to be self-reliant;
- Build on and assess existing local weed and soil management practices as to foster changes in farmers' cropping practices;
- Document and evaluate the impact of the learning process on farmers' livelihoods in order to develop curriculum components for Farmer Field Schools (FFS).

Overview of the dissertation

The introduction situates the weed problem in the current agricultural context. Chapter 2 reviews past research models and discusses their appropriateness to adequately deal with the constraints to agricultural production. It also presents the theoretical framework and research methodology of the thesis. Chapter 3 presents results of the diagnostic study that identified weeds as one of the major constraints to agricultural production. Chapter 4 discusses the social construction of weeds by local communities, officials and researchers. It addresses the question how different perceptions of weeds created the mismatch between scientific knowledge and technical solutions that work under farmers' conditions. It mentions weeding as a form of human labour as an important concept in weed science. Chapter 5 and 6 describe field experiments with farmers in Damè-Wogon and Somè. These chapters focus on strategies to manage speargrass and *Striga*. Chapter 7 assesses the effect of the social learning and joint experimentation on farmers' livelihoods taking into account human and social capital assets. Chapter 8 is the concluding chapter, which critically reflects on the CoS approach with focus on recommendation domains.

Chapter 2

Conceptual framework and overall methodology

Pierre V. Vissoh

Conceptual framework and overall methodology

Conceptual framework

Agricultural research paradigms

Weeds have evolved since the beginning of agricultural activities and remain an integral component of cropping systems. In the tropics, slash-and-burn and fallow are components of traditional land-use systems (Akobundu, 1987; de Rouw, 1995). The fallow period has traditionally been used to control weeds and restore soil fertility. With higher population pressure, this practice is not any longer possible, and agricultural systems evolve towards permanent cropping. In the course of this evolution, the nature of weed problems changed (Chapter 4). However, research developed ineffective weed management solutions, which were not really adopted by small-scale farmers, most likely because labour was not a central category in scientific weed management theories and practices. Weed management is a labour-intensive part of cropping management. Therefore, there is a need to question past research approaches and to suggest alternative research paradigms. While farmers have been innovative in adapting their cropping systems including the adaptation of some of the recommended technologies to their conditions, these adaptations may no longer be appropriate under more permanent cropping.

The ways in which non-agronomic parameters (*e.g.*, socio-economic and cultural factors) affect weed management suggest that research should view weed problems in a more encompassing context of integrated crop management. Addressing weed problems in this larger context and perspective (taking into account biophysical, socio-economic and cultural factors) implies a paradigm shift towards multiple perspectives through which both the natural and social sciences, and modern science and indigenous knowledge can work together in order to meet the need of small-scale farmers.

It is in this trans-disciplinary process-driven approach (Hounkonnou *et al.*, 2006) that the programme Convergence of Sciences (CoS) opened up spaces for learning with farmers after a diagnostic study phase that included negotiation of research agendas with farmers. This chapter first reviews past research paradigms with a focus on weed management, and then suggests appropriate and feasible weed management strategies that emerge from an interactive science with a trans-disciplinary approach embedded in mutual social learning and action within the framework of CoS.

Evolution of agricultural paradigms

Transfer-Of-Technology

In the conventional paradigm, innovation is a result of a linear process by which scientific knowledge is applied in practice (Röling, 1996). Transfer-of-Technology (ToT) represents a classic example of scientists achieving results with a top-down approach during the Green Revolution era (Biggs & Smith, 1998). The ToT model led to the generation of technologies that were considered widely applicable by farmers irrespective of the context in which they were to be implemented (Pretty, 1994). ToT goes together with a belief in diffusion and in the treadmill, as a consequence of which the number of farmers decrease, average farm size increases, farming becomes more efficient and more competitive in international markets, and prices of agricultural products decrease over time (Van Huis *et al.*, 2006).

In that process of agricultural intensification, chemical weed control (through herbicides) was recommended as alternative to hand/hoe weeding to overcome labour shortage. This shift should also alleviate the drudgery associated with hand weeding. ToT seemed to work quite well in specific conditions, but it seemed not to be sustainable, especially because industrial and green revolution agriculture eventually requires support by input or output subsidies (ILEIA, 1991). Policies based on the ToT model tend to marginalise small-scale farmers. Biggs (2006) reported that to be eligible for government credit, farmers had to sign up for fixed technology packages. However, most, if not all, small-scale farmers could not afford these expensive packages (Chambers *et al.*, 1989). Consequently, the impact of the ToT approach in most rainfed areas of sub-Saharan Africa has been extremely limited (ILEIA, 1991). For instance, the rate of adoption of herbicides by small-scale farmers is extremely low. The majority of them was not even aware, had never seen them, nor tested them. For instance, Labrada (1996) reported that the use of herbicides in small farms was not extensive in the developing world and that farmers were not regularly trained in their appropriate use. In these circumstances, small-scale farmers continued to cope with weed problems, being dependent on older crop and weed management strategies such as hand/hoe weeding, tillage/ridging, intercropping, crop rotation, burning during land preparation, and mechanical weeding (*e.g.*, animal drawn power – where cattle are available, as in the cotton area). The ToT paradigm is often too much of a straightjacket because it disregards the local context in which the majority of the farmers operate in favour of generalisable solutions (Castillo, 1998).

Critics, especially social scientists, have expressed concern about the economic, social, political, and ecological consequences of such programmes (Chambers & Jiggins, 1987; Freebairn, 1995; Richards, 1985; 1997; 2001; Röling & van de Fliert, 1998; von Braun, 1989).

According to these authors, this paradigm of technology development and transfer cannot guarantee sustainable agriculture. Such criticism eventually resulted in the formulation of new approaches, such as the Farming Systems Research approach (*e.g.,* Collinson, 2000).

Farming Systems Research

Farming Systems Research (FSR) emerged in the mid-seventies as a new agricultural research and development (R&D) approach. Unlike the linear model, FSR approach tends to view the whole farm as a system managed by farmers. There was an increasing recognition of programme managers, station-based scientists and field extension staff of the need to understand indigenous agricultural knowledge, and farmers' technology and natural resource management practices (Jiggins, 1989).

The evolution and application of FSR are related to participatory technology generation and adaptive research in the form of on-farm research (OFR), which embraces both FSR and its application in on-farm experimentation (OFE), as components of the entire R & D process (Collinson, 2000). Extension staff worked with farmers to identify their problems and researchers recommended new solutions which were tested at farm level in different agro-ecological zones. The results served to generate hypotheses for new trials and to influence on-station research priorities. For instance, cover crops (e.g., *Mucuna pruriens var. utilis*) were recommended to farmers as a dual-purpose technology to raise soil fertility and suppress weeds such as speargrass (*Imperata cylindrica*). Likewise, N_2-fixing legume trees such as *Leucaena leucocephala*, *Gliricidia sepium* and *Acacia auriculiformis* were recommended to farmers in alley farming (Kang & Reynolds 1986). These technologies have created more problems than they have solved. Their adoption was constrained by land shortage and security of tenure and usufruct rights. Furthermore, undesirable establishment of *L. leucocephala* after seed germination resulted in labour requirements for additional weeding. FSR was still dominated by the linear model of thinking in agricultural research. The notion of farmer participation in FSR was also criticised due to weaknesses in its implementation (Collinson, 2000). The low acceptance of its recommended solutions resulted in criticism of this research model and the emergence of another paradigm for rural development with the promotion of active participation, empowerment and poverty alleviation (Collinson & Lightfoot, 2000).

Participatory Technology Development

The farmer participatory research approach (FPR), also called participatory technology development (PTD), emerged in response to a growing dissatisfaction with the poor rates of adoption of agricultural technologies in resource-poor farming systems. PTD aims to enhance farmers' capacity to adjust their farming system, and more inclusively their entire livelihood system, and offers a way forward through active decision-making and involvement of farmers in every stage of technology development (Haverkort, 1991; Horne & Stür, 1999; Jiggins & de Zeeuw, 1992; van Veldhuizen *et al.*, 1997). PTD seeks to reinforce the existing creativity and experimental capacity of farmers, and to help them keep control over the process of generating innovations. It can be an integral part of community-based extension approaches. The basic advantages of PTD are: (1) it builds trust between farmers and outsiders and this helps to build farmers' confidence, tapping their potential for innovation and initiative; (2) it strengthens the links between indigenous and scientific knowledge. Farmer participation also raises a number of questions of central importance about participation. How should farmers participate, for what purpose, and at which stage of the research process? The concept of participation has undergone important changes, varying from nominal participation to collective action.

More details are reported by Pretty (1994, 1995), based on the different ways development organisations interpret and use the term participation. He distinguished the following modes of participation:

1. Passive participation: people participate by being told what is going to happen or has already happened without listening to people's responses by external professionals;
2. Participation in information giving: people participate by answering questions posed by extractive researchers using questionnaire surveys or similar approaches without being given the opportunity to influence, share or check the accuracy of proceedings;
3. Participation by consultation: people participate by being consulted, and external agents listen to views, define both problems and solutions, which they may modify in the light of people's responses, but professionals are under no obligation to take on board people's views;
4. Participation for material incentives: people participate by providing resources, *e.g.*, labour, in return for food, cash or other material incentives. Much on-farm research falls in this category, when farmers provide the fields in exchange for project benefits. Farmers are not involved in the experimentation or the process of learning, and therefore have no interest in prolonging activities when the incentives end;
5. Functional participation: people participate by forming groups to meet predetermined objectives related to the project. Such involvement tends to be achieved after major negotiations, and institutions formed tend to be dependent on external initiators and facilitators, but may become self-dependent during the process;
6. Interactive participation: people participate in joint analysis, which leads to action plans and the formation of new local institutions or the strengthening of existing ones, using interdisciplinary methodologies that seek multiple perspectives and make use of systematic and structured learning processes, whereby groups take control over local decisions, and

people have a stake in maintaining structures or practices;

7. Self-mobilisation: people participate by taking initiatives independent of external institutions to change systems. Such self-initiated mobilisation and collective action may or may not challenge existing inequitable distributions of wealth and power.

Under interactive participation, knowledge construction by both farmers and scientists is necessary for arriving at useful outcome (Biggs & Smith, 1998; Nederlof *et al.*, 2006; Röling, 1996). Under this mode of participation, farmers have the major say in the research process. Richards (1985) stressed that local ecological skills and initiatives cannot be ignored as peasant farmers are often the only experts on local ecological conditions, and the problems and opportunities posed by such conditions. Consequently, research efforts must be a partnership between 'formal' science and 'community ecological knowledge'. Because science's and farmers' understanding may be different and require different research styles, there is a need for constructing understanding. This is where the formal research system actively strengthens the informal R&D system at the farmer, village and community levels.

Farmer Field School

Once we build on the locally existing weed management practices to co-develop appropriate and desirable technologies in farmer research groups, Farmer Field School (FFS) approaches will be used to involve more farmers in the integrated weed management strategies that were developed. According to Röling (2002) and Scarborough *et al.* (1997), FFS emerged out of the ruins of ToT and its conceptual foundations in positivist science, treadmill economics and diffusion of innovations sociology. The complex message involved in integrated pest-management (IPM) proved impossible to get across to farmers through traditional extension methods. Green-revolution technology with calendar-based spraying of heavy doses of pesticides led to resistance and resurgence of pests. Ever-stronger pesticide mixes had to be used leading to farmer death, environmental destruction and farmer indebtedness, while pests such as the brown plant hopper that had never been a problem before, came back and destroyed crops (Mancini, 2006; Rahman, 2000; Röling & Wagemakers, 1998; Thijssen, 2002). It turned out to be impossible to transfer IPM approaches to farmers by way of T&V and other regular approaches to extension, and for that reason a farmer education method was necessary.

Therefore, the main objectives of FFS were to improve farmers' analytical and decision-making skills, develop expertise in IPM and end dependency on pesticides as the main or exclusive pest-control measure. Ultimately, FFS seeks to empower people to actively solve their pest problems by fostering participation, self-confidence, dialogue, joint decision making and self-determination. The empowerment effect of the FFS is based on engaging farmers in a process of group discovery learning that allows them to make their own observations, draw their own inferences and make their own informed decisions (Röling, 2002; Scarborough *et al.*, 1997; van de Fliert *et al.*, 2002). Linking participatory research (PR) to the FFS approach fully integrates research and learning activities in co-research and co-learning. In this regard, farmers' indigenous technologies and local knowledge are indispensable allies in development efforts (Röling, 2002). FFS can foster local dynamics (Hounkonnou, 2001).

Bruin & Meerman (2001) stressed that the available knowledge on a crop, the cultural practices and the ecology determine the development route of a FFS; if little is known, the development of a FFS curriculum must be preceded by phases of learning and PTD. Röling (2002) argued that FFS is not a form of extension at all, but must be seen as a form of agricultural education that develops human and social capital while conserving natural capital. He also pointed out that empowered, self-organising farmers, in turn, can become much more effective partners in extension. Similarly, the International Potato Centre-Users' Perspectives With Agricultural Research and Development Programme (CIP-UPWARD, 2003) reported that increasingly FFS is considered as a form of social learning and collective action. A FFS is organised by a facilitator who does not act as a teacher or a trainer (conventional approach), but facilitates a process of learning (van de Fliert, 1993).

The present thesis on weed management strategy development is based on the PTD approach. It supports the view that an open-ended PTD process is a useful precursor to FFS, in that PTD allows developing technologies. The findings can then form the basis for FFS curriculum development.

Experiential learning perspective cycles

The purpose of action research is to learn from experience, and to apply that learning to bring about change through a process of iteration (Dick, 1993). Thus social learning can be interpreted as a dynamic process, which involves continuous sense-making of the world through perspectives or frames of reference, based on concrete experience modified by knowledge, beliefs, and values (Dangbégnon, 1998; Maarleveld & Dangbégnon, 2002). Social learning can take the form of an experiential learning cycle (Fig. 1).

Learning is the fundamental process of human adaptation (Kolb, 1984) or co-adaptation (Bawden, 1991). In line with this experiential learning cycle, a social learning perspective is concerned with both action and reflection. Experiential learning views action as a basis for learning, what Kolb calls learning by doing. Concrete experiences may be reason for reflection. One's window on the world (normative cognition frame) determines which issues are viewed as problematic and which are not. Abstract conceptualisation may lead to the development of new ideas. These ideas need to be tested in practice, which leads to new concrete experiences and the cycle evolves (Maarleveld & Dangbégnon, 2002).

Linking up with local people certainly helps to discover their real priorities and the way they get organised to deal with them, which in turn makes it possible to build upon what local people are doing. This study builds upon indigenous practices to foster social change in farm management practices to keep weed problems at a low threshold level. This is possible through joint learning. Purposively I opted for building local platforms (learning groups) with representatives of different stakeholders who were involved in the whole research process, so that they contributed to the co-construction of knowledge through discovery learning. Given the limited effectiveness of conventional weed science in addressing the problems of resource-poor farmers in West Africa, such a radically open-ended and participatory approach seemed called for. Our approach required not only goal-seeking research, given the goal, but an analysis of human intentionality, culture, and institutions to determine appropriate goals.

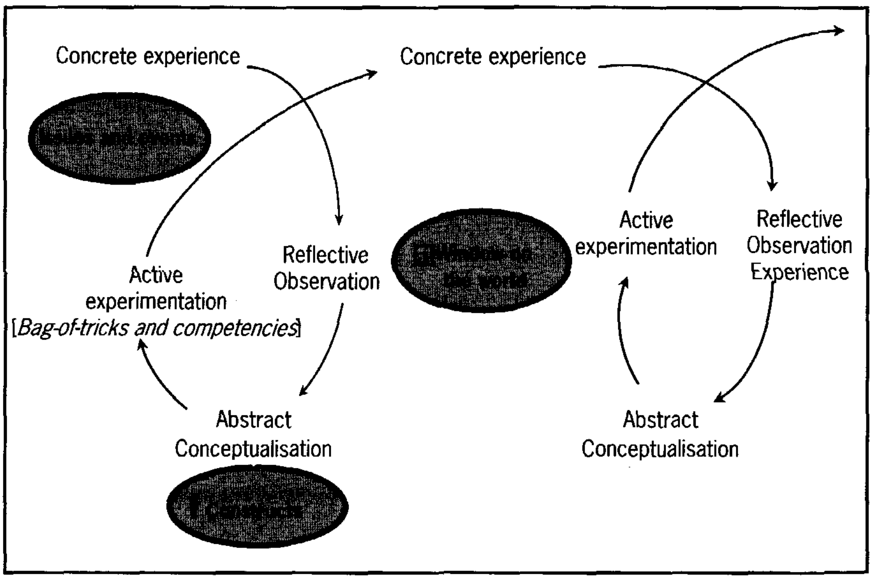

Figure 1. The experiential learning cycle. Based on Kolb (1984) and adapted from Hounkonnou (2001) and Maarleveld & Dangbégnon (2002).

Joint experiment for knowledge construction and social learning

Weed problems are not just technical; they are also socio-economic and cultural. The development of any effective and appropriate management strategies should therefore address both aspects. Local practices were used as a starting point. A common research agenda was negotiated and agreed upon with local platforms of farmers after revisiting the diagnostic study results (Vissoh *et al.,* 2004). Research topics as well as protocols were elaborated and established with the platforms of farmers to take into account the local context and needs of the farmers. Learning was iterative and interactive and multiple perspectives were facilitated through tension, power, conflict, negotiation and agreement on concerted action. There was a need to deconstruct and reconstruct knowledge within the local context to give farmers a chance to increase their knowledge and improve their weed management strategies by doing.

Research methodology

Study area

Two villages located in the southern Agro-ecological Zone of Benin were selected, *viz.* Damè-Wogon and Somè.

One study was carried out in the sub-district of Damè-Wogon where speargrass is a major constraint to crop production. Damè-Wogon is composed of 5 villages (Fig. 2) and enjoys the proximity of the Ouémé River, which offers farmers the opportunity to crop both the plateau and the bottom valley during the subsidence of the river and to practise fishing. Agriculture is the main occupation of the people. The major crops grown are maize, cassava, cowpea, groundnut, cotton, and oil palm on the plateau and vegetables, cowpea, and maize in the valley. Yam was cultivated in the past, but cultivation has been discontinued due to soil fertility decline and land shortage. Secondary occupations include trading due to the proximity to Nigeria, processing of agricultural products and animal husbandry, and fishing. Young people temporarily migrate to Nigeria to offer their service in the plantations. After buying goods such as motorbikes, they usually return at Christmas to celebrate the New Year.

Somè is located in the district of Za-Kpota of the Zou Department on the Abomey plateau (Fig. 3). The cropping system is presently made up of oil palm trees intercropped with annual crops and oil palm fallow. Maize and sorghum are the major staple food crops grown. Their production is severely constrained by soil fertility decline in combination with parasitism by *Striga hermonthica*. There is a loss of crop diversity, due to land shortage, soil fertility decline and damage caused by granivorous birds. Crops such as yam and millet are no longer cultivated. Crops grown include cowpea, groundnut, bambara groundnut, and soybean because they can still (but poorly) grow on impoverished soils. These legumes could also add nitrogen to the

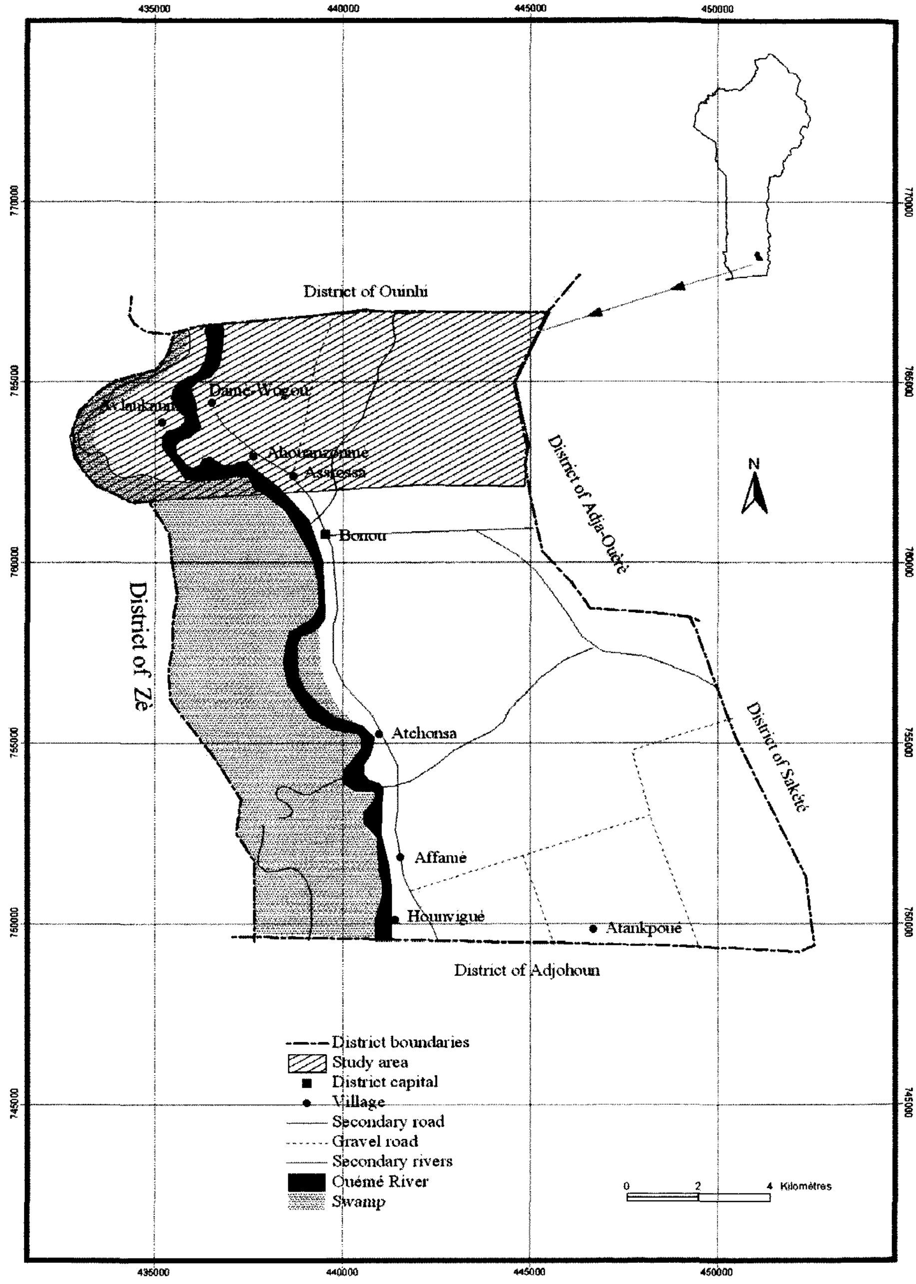

Figure 2. Map of Bonou district showing the speargrass study area

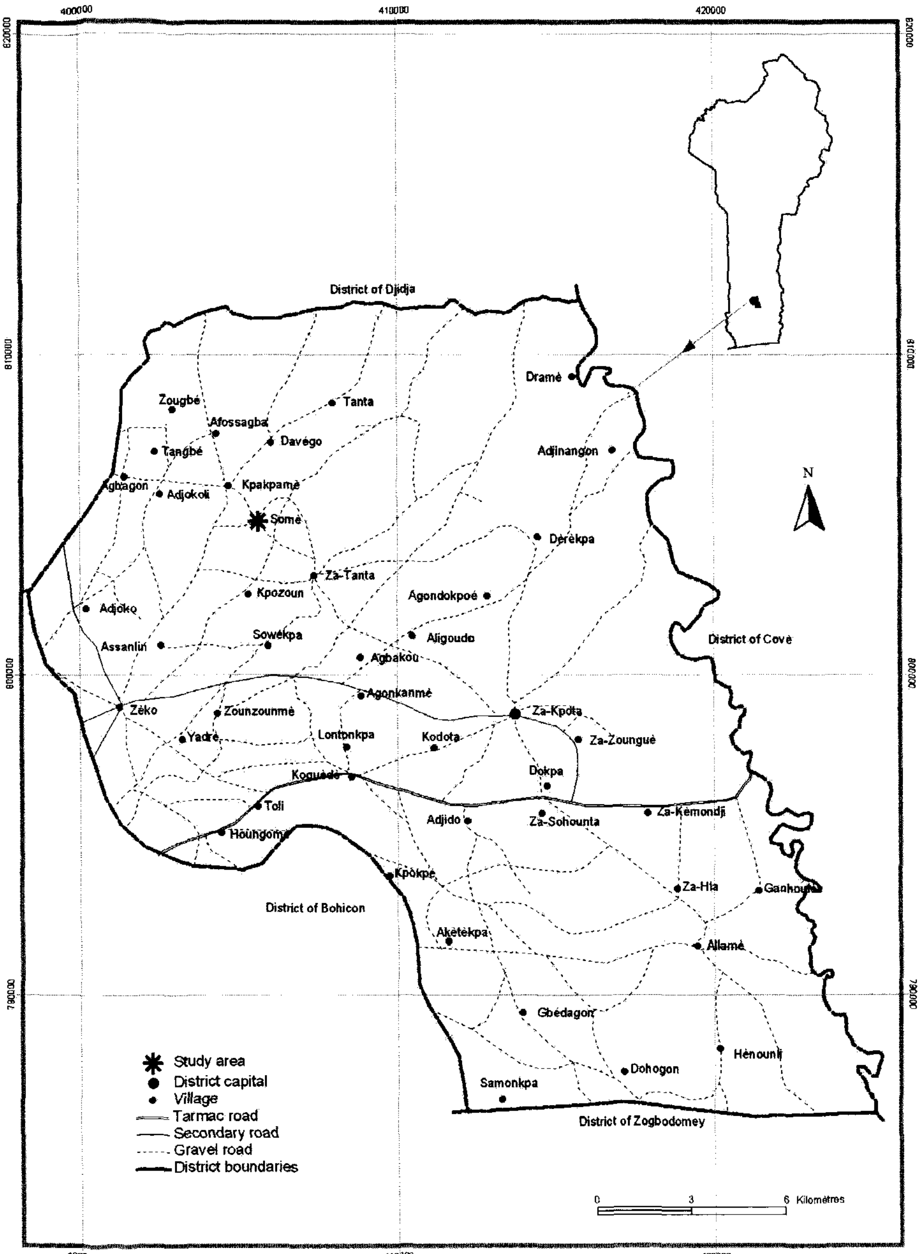

Figure 3. Map of Za-kpota district showing the *Striga* spp. study area

subsequent cereal crops on plots around the homesteads, but because of low productivity of the legumes and the lack of other amendments, cereal yields remain very low. Maize is grown away from the village (about 1km) where soils are still somewhat more fertile and less infested by *Striga*. Cotton is being progressively abandoned as the sector is in crisis and farmers run into debt. This has affected fertiliser availability. In these bleak conditions, migration seems an alternative for survival and it has reached its highest point from 1992 to 2002. This migration represents a loss of human resources.

General methodological orientation: action research

Action research subsumes a variety of established methodologies including action learning, action science, participatory action research, and soft systems analysis (Dick, 1993). The same author pointed out that action research is an important innovation in social inquiry because it enables research to take place in the context of real-life situations and to address issues of power relations between the researcher and the researched. It also offers people a chance to make more use of their practice as a research opportunity. In other words, action research is a particular way of critically learning about events in this world in order to change them (Bawden, 1991). It combines theory with practice in a critical process. For that reason I opted for an action research methodology to develop weed management strategies that farmers can adopt.

In-depth studies

In-depth studies were carried out in the selected villages (Damè-Wogon and Somè) to acquire a deeper insight into the farming practices and problems with which farmers are confronted, with a focus on weed problems. The selected weed management strategies (chapter 3) were also studied in depth the first year in order to develop with the local learning groups weed improved management practices.

Based on the assertion that participating in local life means that ethnographers constantly talk to people and ask questions about what they observe (Kottak, 1991), my stay in the villages during three years allowed personal connections including enduring friendships to be developed that facilitated the in-depth study on farm management in general, and weed management in particular. In this respect, I tried to maintain permanent contact with members of the learning groups and non-participating farmers either in their fields or at home, sometimes sharing meals with them. Various aspects of the farming systems were discussed, mostly in informal conversations.

Direct, first-hand observation of decision-making and behaviour, including participant observation of farm activities

Participant observation enabled me to understand why farmers do this and not that, *e.g.*, establishing sorghum nurseries before planting instead of direct planting, their choice of cowpea cultivar(s), or their preference for different planting periods (early *versus* late planting). This also enabled me to take part in the ritual ceremonies when long drought spells occurred and to understand norms, religious beliefs and cultural practices that contribute to the performance of the farming systems.

Conversation, interviewing and listening to narrative accounts

Using a checklist made up of key points to be collected, open-ended, semi-structured interviews, and informal conversations were used to date events and collect data. The checklist addressed the following issues: Were weeds a problem in the past? When and why did weeds become a problem? Has labour (availability) become more of a problem? Was speargrass a problem before iron-sheeted roofs became widely used? The technique of genealogical/family tree was used, *e.g.*, a man would tell you what happened when he was young and what his father and/or grandfather told him about the time when they were young. Historical information was also collected from people with different experiences (old, middle-aged and young males and females). The historical accounts were checked through triangulation and the literature. Key informants were identified through the snowball technique. Changes were documented. Transplanting techniques, field experimental content and social-economic dimensions were described and analysed to obtain insight into the social construction of realities and especially weeds. The research process was documented not only from a social perspective but also from a biological perspective, in an attempt to arrive at beta/gamma integration.

Literature review

Response of formal agricultural research was sorted out through technical notes, annual reports, and workshop proceedings of national, regional and international research and extension institutions. Research and extension agendas were analysed to better understand when weed invasion was prioritised and translated into research actions. The current level of adoption of recommended weed management technologies was reviewed including the various constraints that hampered their adoption at farm level.

Archival research

Archival research provided a source for triangulation with oral historical and life history interviews. It provided information on colonial policies affecting agriculture in general, and on the extent to which weeds were a concern during pre-colonial, colonial and post-colonial eras. Archival research was conducted at the *Centre National des Archives* located at Porto-Novo, the administrative capital of the country.

Quantitative survey

A quantitative survey was carried out to collect basic information on prevailing land tenure systems, on the spread of selected weed management practices in selected villages, on the typology of holdings and farm sizes, and on the different sorghum transplanting techniques in Somè, and different speargrass suppression strategies in Damè-Wogon.

Joint field experiment with farmers

Field experiments were jointly conducted with farmers in Damè-Wogon to build on farmers' practices and evaluate their effectiveness to suppress speargrass and improve subsequent maize yield in a permanent land use system. Similarly in Somè, various experiments were carried out with groups of farmers focusing on *Striga* spp., to assess the effectiveness of measures to reduce *Striga* interference on cereals and cowpea. In both villages, before the experiments took place, discovery learning sessions enabled farmers to increase their knowledge of the biology of each weed species.

Chapter 3

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

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NJAS – Wageningen Journal of Life sciences 52: 305-329. 2004

Chapter 3

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

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 (I) 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 commodities 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.

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 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). Speargrass (*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 cleared. 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, SG200'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.*, 2004) 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 (INRAB, 1995). For the different agro-ecological zones and their characteristics see Table 1. The map in Fig. 1 shows the location of the agro-ecological zones and the villages that were visited during the diagnostic study.

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 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 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.

Table 1. Characteristics of the five agro-ecological zones of Benin.

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 alphabetic order.
Source: INRAB, 1995.

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.

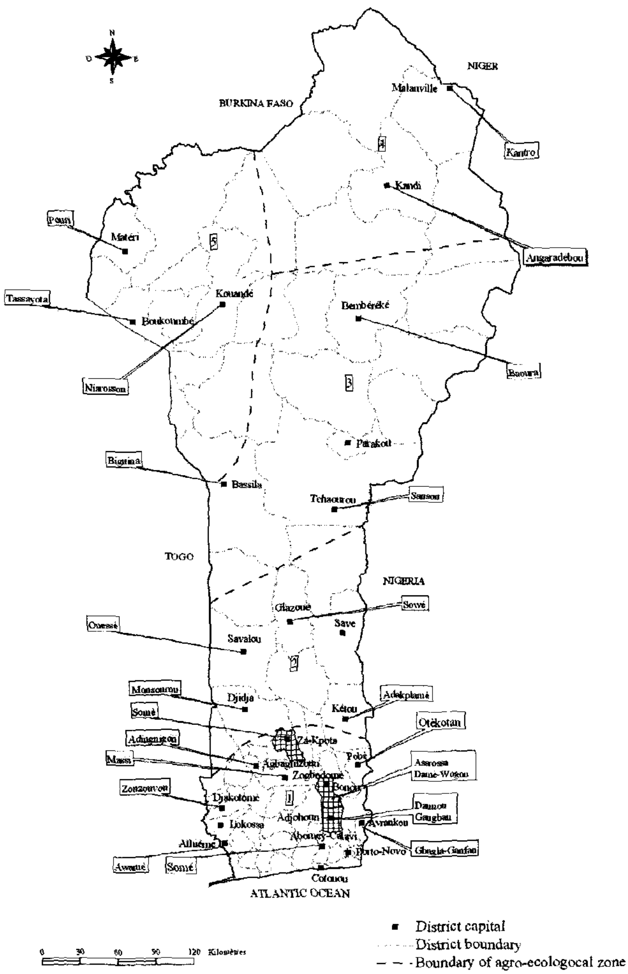

Figure 1. Map of the Republic of Benin, indicating the 5 agro-ecological Zones (1-5), the village visited during the study and the districts selected for the in-depth studies (hatched). 1 = Southern Zone, 2 = Transition Zone, 3 = Southern Borgou/Southern Atacora Zone, 4 = Northern Borgou, 5 = Atacora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

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' (GF) 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 transects studies. Transects were carried out to verify information provided by farmers on soil types and weed species. The tools used were village maps, checklists, 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 weed, (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, commodities prices and the 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 human 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' (INSAE, 2003), 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 degraded 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,* and *Imperata cylindrical* (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 of four to five years (Table 2). However, such fallow periods are not enough for soil fertility restoration and weeds control. According to Pieri (1989), prolonged fallow periods of 10 years in dry Savannah areas and up to 30 years in humid area are needed to stabilize traditional production systems like shifting cultivation. However, there are production systems

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]	Others[3]
Southern Zone							
Gbagla-Ganfan	1031	No fallow	1	2	3	4	
Dannou, Gangban	202	No fallow			2	1	3,4
Assrossa, Dame-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							
Niaronson	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 districts where the villages are located. Source: INSAE (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).

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 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 (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 total amount of annual rainfall during the period of 1971-2000 compared with that of 1941-1970. This decrease is even significant in the Northern part of the country. He observed 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 vegetative 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 decades (1981-1990). A similar trend was observed at Bohicon. These observations are consistent with the findings of Houndénou (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 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) (INSAE, 2003). 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 areas. 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 ha 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 regard, 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 soil and rainfall patterns.

The production system in northern Benin is characterized by an even lower human 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 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 Boukoumbé, 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 include *Imperata cylindrica* (speargrass) 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). Speargrass is also a major weed in Adingnigon and Somè. According to the farmers interviewed, witch weed causes more damage than speargrass and it is easier to reclaim plots infested by speargrass than plots infested with witch weed, which apparently nobody can control. Other major weeds are *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 this 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 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 40,000F 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 speargrass by using herbicides more beneficial than hand weeding. Furthermore they usually weed speargrass plots more than two times. This finding is in accordance with that of Chicoye *et al.* (2002), who reported that chemical control of speargrass resulted in higher benefits than hand weeding. The use of herbicides led to a better control of speargrass, 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.

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, Dame-Wogon	1	2	3	4		
Otèkotan	1		3	4		2
Somé	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						
Niaronson			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* (2x), *Brachiaria* sp., *Eichhornia crassipes, Echinochloa pyramidalis, Ipomea* spp., *leersia hexandra, Mariscus alternifolius, Paspalum vaginatum, Rottboellia cochinchinensis* and *tridax procumbens*)

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})	Cost (€ ha^{-1}) Hand weeding	Cost (€ ha^{-1}) 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.

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 speargrass 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 so 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 weed 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 6000F 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 a 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 *Ipomea 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 plant infertile'. All the 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 cultivate 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* (speargrass) 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 speargrass 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 and 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 speargrass'. As a strategy to control speargrass, 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 ('egussi') on the ridges covers the soil and prevents the re-growth of speargrass and restores soil fertility. Farmers prefer those technologies that have multiple effects so that their practices are beneficial for weed control (e.g. cowpea, melon and cotton), 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, groundnuts and 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 damages. 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 Zone, 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 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 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 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 speargrass, 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 & Dangbénon, 2004). Likewise, the woody legume *Acacia auriculiformis* was recommended to farmers for suppressing speargrass, but farmers rather plant it to produce firewood, as their environment is completely deforested.

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	+
		Crop associations (cereal-legume)	+	Use of herbaceous Legume cover crops (*Mucuna* spp.)	–
		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.

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 Zone) 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 such as 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 to control *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 weeds problems based on farmers' perceptions (Fig. 2) still persists in spite of research recommendations.

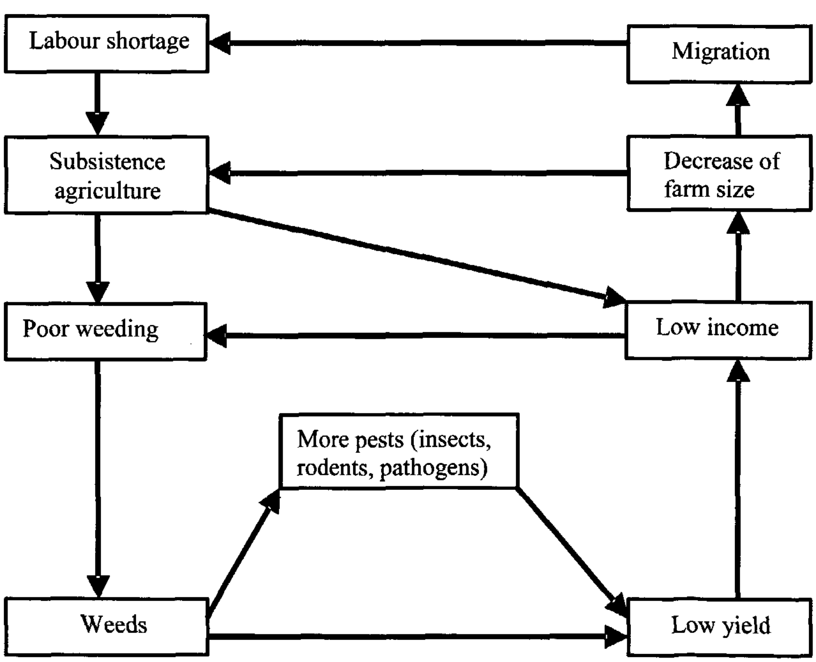

Figure 2. The vicious weed circle.

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 can be envisaged: (1) provide credit to farmers, or (2) improve their knowledge to allow them to manage weeds efficiently at a lower cost. However, 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. 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 action 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 of 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 for 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 speargrass 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 a 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; CIP-UPWARD, 2003), 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, transects 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 premium 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 further 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 Dame-Wogon) (Figure 1) to deepen the data collected during the diagnostic study.

Conclusion

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 labor 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 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.

Chapter 4

The social construction of weeds: Different reactions to an emergent problem by farmers, officials and researchers

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International Journal of Agricultural Sustainability (Accepted in April 2006)

The social construction of weeds: Different reactions to an emergent problem by farmers, officials and researchers

Abstract

Rapid population increase in southern Benin has changed the prevailing system of shifting cultivation into one of more permanent land use. New herbaceous weeds exacerbated rural poverty through crop failure, higher labour inputs, rising costs of production, and reduced availability of suitable land. We investigated how different actors reacted to the emergence of weeds, in terms of the construction of knowledge, labour practices and technology development. Weeds have become an important cause of rural poverty. Farmers have actively engaged in technology development and new labour practices have emerged. Officials early on did report weed problems, especially where export crops were concerned. Researchers have not translated the new weed problem into a research priority until very recently, resulting in limited and inappropriate weed management technologies. The challenge of the research of which this study is part is to optimise weed management, by combining emergent indigenous weed management practices with scientific knowledge.

Keywords: indigenous technologies, labour shortage, permanent land cultivation, population pressure, rural poverty, stakeholder diversity

Introduction

Weeds induce substantial crop losses and have an important impact on smallholders' revenue. Weed control is labour intensive. It can consume between 30 to 54 % of the total amount of labour used on an African farm, depending on the crop and the level of other available resources, and it takes about 280 hours of labour to weed one hectare twice (Okon & Amalu, 2003). In all, weed reduction is an important component of the quest to reduce rural poverty in Africa. However, formal science has made insufficient impact in addressing and solving weed-related problems.

Weed-related problems raise interesting questions with respect to how different groups perceive and react to weeds. In this paper, we focus on farmers, (colonial) officers and agricultural researchers. At a more theoretical level, the paper discusses the issue how the weed problem became socially constructed (Berger & Luckman, 1966; Hacking, 1999) by different groups and what the consequences were and are for dealing with the problem. What makes weeds in Africa especially interesting from a constructivist point of view is that within living memory, the issue of weeds has undergone a transformation in African farming systems. Population pressure on land has led to a very rapid decline in fallow periods from sometimes more than twenty to four or five years (Weber *et al.*, 1995a; Mateete *et al.*, 1997; Vissoh *et al.*, 2004). Where formerly weeding had to contend with re-growth of trees and shrubs, more permanent land use has given rise to the emergence of herbaceous weeds that sharply reduce yields and greatly increase the labour required to grow crops (Weber *et al.* 1995a). Weeds posed new problems that rural people had to cope with, and became a component of the vicious circle of poverty in small-scale farmers' production systems (Vissoh *et al.*, 2004). This transformation in the nature of weeds and weeding requires a concomitant transformation in the cognitive and social domains: naming weeds, inventing, testing and diffusing technologies, adapting farming practices, and changing labour deployment and prices.

In this paper we describe the emergence of novel herbaceous weeds in selected farming systems in Benin. We focus on *Imperata cylindrica* (speargrass or Cogongrass, Alang Alang), a pioneer plant whose rhizomes rapidly invade arable fields and which is very difficult to eradicate; and on *Striga hermonthica* (witchweed), a parasitic plant that thrives in conditions of soil degradation and destroys cereal crops such as sorghum and maize. We also describe ways in which Benin farmers adapted to these weeds. The principal author has an emotional stake here. He grew up on a small family farm and spent many hours of back-breaking labour to weed his father's fields. We also trace how government authorities reacted to weed problems. Finally, we analyse the reaction of formal agricultural research to the emergence of weeds in Benin. But first we provide a quick overview of the attempts to define weeds and provide a short background to the social construction of reality.

The definition of weeds

The definition of weed has always given rise to controversies, even among weed scientists. Not all people agree what a weed is or which plants are weeds. Scientists' most common definition is that a weed is a plant that grows where it is not desired (Reijntjes *et al.*, 1992; van Rijn, 2000; Zimdahl, 1993). Weed control is not necessarily the eradication of unwanted plants but an activity aimed at decreasing or removing the interference. Farmers have learned to manage populations of weeds and to strike a balance between competition, soil protection and weeding costs (Oyen, 1995). Traditional farmers make a distinction between good weeds, which are often not even seen as weeds, and bad weeds. The definition of weed as 'a plant whose virtues have not yet been discovered' (Godinho, 1984; Zimdahl, 1993) connotes that it is humans who decide whether a plant is a weed or not, depending on context (time, space, socio-economic and cultural conditions), and the balance between the perceived negative and positive aspects of a plant. Weeds have, therefore, not only been considered as pests to be eradicated; some of them are also useful plants for medicinal purposes, soil fertility management, pest control, construction material, food for people and animals, and various other purposes (Akobundu, 1987; Alcorn, 1995; Delabarre, 1977; Obatolu & Agboola, 1993; Okon & Amalu, 2003; Reijntjes *et al.*, 1992; Slaats, 1995; van Rijn, 2000). There is no single 'objectively true' way to look at weeds. Instead, the multiple perspectives on weeds underscore the fact that humans depend on active social construction and learning to deal with important phenomena in their domain of existence. Only if one accepts the multiple realities that people construct, can one explain why one person's devastating weed may be another person's valuable plant.

Constructivism and the social construction of knowledge

For the purposes of this article, it is necessary to briefly introduce constructivism, especially because it is not a perspective that is common among agricultural scientists. Constructivism views knowledge as 'constructed', because it does not project the outside world on the brain. Instead, humans actively construct knowledge depending on social experience, learning, convention, culture, etc. Constructivism has given rise to science wars (Hacking, 1999) as philosophers and scientists with different metaphysical and epistemological persuasions bitterly fought each other about that nature of knowledge and truth. Our interest in social constructivism derives from our conviction that understanding the ways in which different groups constructed (knowledge) of weeds and on the basis thereof constructed weed management practices, helps us to understand the mismatch between technologies proposed by formal science and farmers. Phrased differently: the science arena in which weeds are investigated lies outside the farmers' arena where weeds are experienced. Understanding this mismatch could then contribute to designing together with farmers novel ways of weed management practices that are acceptable to farmers and work under their conditions.

Hacking (1999) identified three main issues ('sticking points') on social construction, *viz.* contingency, nominalism and explanations of stability. The *contingency* thesis implies that a successful science did not have to develop the way it did, but could have taken a very different route. As we will make clear in this paper, the contingency thesis makes sense in weed science. Weed science could have developed differently, depending on its relative focus on the soils in which weeds thrive (weeds as a problem of soil fertility), on the plants and their interactions with crops (yield decline through weeds) or on the way humans manage such plants (weeding as a basic concept in weed science). However, that conclusion should not be construed as a general claim that our knowledge of the world is only determined by how people perceive it and frame it in terms of language, experience, and needs (the issue of *nominalism* versus realism); in other words, the claim that weeds only exist in the mind of farmers, weed scientists and others. Such a version would ultimately entail the claim that weeds exist because (and since) weed scientists claimed their existence and nuisance. We do not subscribe to that view. Not every construction can be effectively and justifiably deconstructed. Adaptive social construction has the very purpose of arriving at effective action in a predictable environment. The effective farming systems that African farmers have, over time, developed stand as testimony to this process (Röling, 2003).

Hacking's third sticking point refers to internal versus external explanations of *stability*. As this paper will also show, perception and knowledge of weeds by the different groups have their own histories. Weed perception and management by farmers changed due to agricultural intensification leading to the emergence of novel weeds. Weed perception and technology development by scientists and government officials also changed due to a shift in attention from export to subsistence crops, to the emergence of new weeds, and to the increasing awareness of weeding as a human practice.

Methodologies

Study area and the villages

An in-depth study was carried out in the villages of Damè-Wogon (District of Bonou), located in the Ouémé valley, and in Somè (District of Za-Kpota), situated on the Abomey plateau. Both villages are located in the southern agro-ecological zone of Benin. Land pressure is higher in Somè than in Damè-Wogon as population density in Za-Kpota district is nearly twice that of Bonou district. The land tenure system in both villages is based on inheritance, which means in the traditional setting that sons gain control over the land when their father dies. Other forms of land acquisition include borrowing, while in Somè renting, and in Damè-Wogon sharecropping and pledging have emerged as new ways of gaining access to land. In recent times distress sales of land have also taken place. Data collected during an earlier diagnostic study (Vissoh *et al.*, 2004) were complemented by novel information to give a more complete picture of how farmers perceive weeds.

Data collection

This article reports on work that is part of a larger study that includes experiments with farmers to test and adapt weed management technologies in accordance with farmers' socio-economic realities. Many of the technologies tested comprise indigenous technologies. These technologies are part of our analysis of the social construction of weeds by farmers. Additional data were collected, using a combination of methods, comprising:

(1) Archival research at the *Archive Nationale* and *Bibliothèque Nationale* at Porto-Novo, the political capital of Benin;
(2) Literature review of agricultural research activities and findings through published and unpublished articles, annual reports, and workshop proceedings of national and international research institutes (INRAB, University of Abomey-Calavi, IITA, IFDC and various NGOs);
(3) A semi-structured questionnaire was used to collect socio-economic characteristics of farmers, the prevailing land tenure systems in the study area, labour use, etc. The questionnaire was administered to 50 randomly chosen respondents (7 women and 43 men in Damè-Wogon; 14 women and 36 men in Somè);
(4) Qualitative data were collected through focus group discussions, participant observation, informal and semi-structured interviews of groups and key informants. Focus group discussions were held with different categories of farmers. The groups included elderly, middle-aged and young, male and female farmers;
(5) Informal discussions were held with weed researchers and extensionists about their concept of weeds and about the responsiveness of agricultural research to emerging weed problems so as to crosscheck information gathered from the literature and farmers.

Data analysis

Data analysis focused on understanding how population pressure led to changes in land use systems, on the causes and consequences of the emergence of weeds, on the impact of weed emergence on labour and its cost, and finally on crop yields and livelihoods. We analysed farmers' names for weeds. We also attempted to understand positive functions of weeds, as well as farmers' adoption of recommended science-based weed management practices. Finally, we analysed the social dimensions of weeds as a new component of the vicious circle of rural poverty.

Emergence of weeds and farmers' reaction to it

Elderly farmers acknowledge that in the past, when land and labour were plentiful, weeds were not a problem. Family labour was abundant. Children did not go to school and were available for weeding. Long fallow periods of more than ten years generally succeeded periods of three to four years of cultivation. The recent increase in population density has resulted in a rapid reduction of fallow periods and a breakdown in farm size from one generation to the other in such a way that the present generation is experiencing acute land shortage. For instance Ahossi's grandfather owned 6 ha. When he died, his plot was divided equally among his five wives to be given to their sons according to the tradition. Ahossi's farther then inherited 1.2 ha, which he distributed to his five sons who each inherited 0.24 ha. Having ten sons, each of them will inherit 0.024 ha when he dies.

Land scarcity and farming history

The break-down of farm size in both villages is alarming, particularly in Somè. The survey revealed that on average, 70% and 78% of the farmers own less than three hectares respectively in Damè-Wogon, and in Somè (data not shown). Land shortage is so critical in Somè that the majority of young people do not have access to land for farming. As an example, Koutika, a young man of about 25 years old, is a landless farmer. He was compelled to borrow a plot of 0.12 ha from his relatives to enable his wife to grow maize. He was forced to migrate to the Department of the *Collines* where he worked as a labourer. He is a driver and during periods when farm activities are relaxed, he usually returns to drive a taxi or ride a taxi-motorbike whenever he manages to obtain access to a vehicle. Five years ago, he travelled to Abidjan (Côte d'Ivoire) in search of employment but he was forced to come back because of the political crisis in that country.

In these conditions, land is continuously cultivated. For instance, Animanonvo, a farmer in Somè village, has been cultivating his land for 40 years. The land was fallowed when he spent about 7 years in Côte d'Ivoire. When he came back about in 1975, he grew cotton and maize for three years. Thereafter he abandoned cotton because he got into debt and grew maize, sorghum, groundnut and cowpea. *Striga hermonthica* was discovered 20 years ago and presently the plot is no longer suitable for maize cultivation. He used to crop the local variety of cowpea Sèwécoun, which became infested with *Striga gesnerioides*. The interference by both *Striga* species is so severe that sorghum and cowpea cannot be produced anymore. Since 10 years he has allowed this land to be used for scientific experiments related to *Striga* spp. management.

During the last three years, the land has been used for participatory development of *Striga* management technology within the framework of the Convergence of Sciences Project.

In Damè-Wogon, farmers crop both the plateau and the valley offering them more opportunities than in Somè. However, speargrass has invaded most of plots cropped continuously. Cowpea varieties are used to suppress speargrass.

Farmers' perceptions of weeds

There is no uniform conception of weed among farmers. In Damè-Wogon, the local term for weed is *Gbégnlancan,* which expresses the more harmful aspects of weeds as plants that compete with crops impoverish the soil, harbour insect pests, and of which their management is laborious and costly. In Somè, in the local language *Fon*, weeds are called *Gbé* or *Gbéhan*, which is any plant that has not been sown but has emerged spontaneously in the field.

The local name for *Imperata cylindrica* is *Sê*, *Enon Sè Doaa* meaning that whatever you do, it does not move. In other words, speargrass is difficult to eradicate. According to farmers speargrass has become a real constraint to agricultural production since about 20 years. Similarly, the local name of *Striga* spp. in *Fon* is *Do* which means death because it inevitably kills the cereal and cowpea. In traditional societies in Africa, death is usually attributed to witches; therefore *Do* refers to witch as well[1].

Harmful and beneficial aspects of weed species

Farmers rank weeds using the following criteria: degree of harmfulness, number of required weedings, and investment in weeding (Tables 1, 2 and 3). Weeds that are marked with three asterisks are those that are highly detrimental to crop yields (Table 1). On the plateau, *Imperata cylindrica*, *Striga* spp., *Commelina* spp., and *Cyperus* spp., are very harmful. In Somè, farmers stated that *Striga* spp. are more harmful and more difficult to control than *Imperata cylindrica.* In the valley, *Oryza longistaminata, Leersia hexandra,* and *Ipomoea aquatica* are considered the most troublesome weeds.

Farmers also consider that most weeds have beneficial aspects. Table 1 presents various positive functions of some weeds. Some are used either as construction materials and/or traditional medicine or provide income (e.g., *Imperata cylindrica*); others are used as vegetable, as animal feed or as soil fertility indicators. Speargrass straw was used as roofing material but nowadays the use of iron sheets is a matter of prestige. Speargrass does not last as long as iron sheets, but thatched houses are cooler and thus more comfortable than those with iron sheets,

[1] However, even though the Latin word *Striga* means witch, and the vernacular name of *Striga* species is witchweed, any connection in the scientific literature between *Striga* and witches is spurious, because the Latin name *Striga* was derived from strigosus, referring to the bristly nature of the stem.

especially during dry seasons. The demand for bundles of dried speargrass in rural areas and in towns has enabled the development of a substantial trade in that weed. Some farmers have developed the sale of speargrass into an alternative to farming and have succeeded in making a decent living out of it. Striga species do not occur in Damè-Wogon. In Somè, farmers do not perceive beneficial uses for *Striga*.

Table 1. Weeds in the different agro-ecological zones.

Weed species	Topo-sequence	Farmers' perception	
		Harmfulness	Use
Imperata cylindrica	Plateau	***	-Construction material -Source of income -Rhizomes are used in traditional medicine
Striga spp.	Plateau	***	Not yet identified
Cyperus spp.	Plateau, valley	***	Nuts are use in traditional medicine
Commelina benghalensis	Plateau, valley	***	- Flowers are used in traditional medicine - Leaves are animal feed
Panicum maximum *Andropogon gayanus*	Plateau, valley	**	-Soil fertility indicator -Animal feed
Tridax procumbens	Plateau	**	Animal feed
Dactyloctenium aegyptium	Plateau	**	Not yet identified
Pennisetum spp.	Plateau	**	Soil fertility indicator
Boerhavia diffusa	Plateau	**	Not yet identified
Centrosema pubescens	Plateau	**	Soil fertility indicator
Leersia hexandra	Valley	***	Not yet identified
Oryza longistaminata	Valley	***	Roofing material in the valley
Hygrophila auriculata	Valley	***	Not yet identified
Ipomoea aquatica	Valley	***	Animal feed
Ageratum conyzoides	Valley	*	Vegetable
Justicia anselliana	Valley	*	Vegetable
Echinochloa pyramidalis	Valley	*	Maintains soil moisture
Acroceras zizanioides	Valley	-	Maintains soil moisture Suppresses weed Improves soil fertility

Legend: ***: very harmful, **: harmful, * fairly harmful, -: not harmful

Source: Field interviews March 2005

However, *Striga* is used as insect repellent, herbal medicine and indigo blue dye in northern Ghana (Lagoke & Hoevers, 1992), while in northern Benin it is used as medicine to cure cattle's colics, as indigo blue dye and as a cure for children with retarded growth (Egbers, 1990; G. Gbèhounou & A. Youèhouénou, *pers. comm.*).

Technology development by farmers

With the invasion of speargrass, farmers in Damè-Wogon, first used to excavate the rhizomes with a special hoe. They realised later that this time, energy, and resource consuming practice reduces arable farm size. They then tested a less stressful strategy, which consists of planting creeping or semi-erect but leafy cowpea varieties after land preparation to suppress speargrass and to improve soil nitrogen and organic matter.

As for *Striga* species, farmers in Somè adapted their planting date of cereals (maize and sorghum) and cowpea to escape from severe infestation. They have also learnt to adapt the crop mix to the soil fertility status and the level of infestation, so that severely infested degraded plots around the homesteads are usually cropped with sorghum, which is somewhat more tolerant than maize. The transplanting of sorghum initially was not used for *Striga* management but it was used to fill gaps in planted rows. But farmers soon noticed that plants transplanted from nurseries in the fertile soil close to the houses tended to withstand *Striga* in an infested plot. In this way, farmers discover solutions to problems even if they do not know how it works.

Weeds as a component of the rural poverty cycle

Farmers of the learning groups formed after the diagnostic study in each village (Vissoh et al., 2004) analysed causes and consequences of weeds. The analysis is depicted in Fig. 1. The root cause of weed invasion is population growth, which has resulted in a substantial reduction of farm size and in soil mining. Out-migration of people in response to land shortage, and the modern practice of sending children to school have both had a negative impact on the availability of labour for agricultural activities. Labour scarcity, in turn, has led to an increase in labour costs, to a reduction in the number of weedings, and consequently to substantial crop losses. Farmers lack the financial resources to invest in weeding or run up debts. Thus weeds force them into a vicious cycle of poverty.

The concomitant food shortfall that results from inadequate weeding threatens food self-sufficiency, and renders poor people vulnerable to diverse illnesses including malaria, tuberculosis and AIDS/HIV, which further reduce already scarce labour. Poor farmers who are incapable of providing the household with proper care and schooling are forced to entrust their children to people who promise to educate them. This phenomenon is usually referred to as *vidomègon*. In return, household heads receive a modest amount of money and the promise to benefit from the dividend of their children's work. Such *selling of children* again reduces the labour force available for weeding. Usually these children are ill-treated once they are in the towns or sent abroad (Côte d'Ivoire and Nigeria). The poorer the villages, the more child-trafficking increases and the more acute labour scarcity becomes. This strategy of escaping from poverty is more common in Somè than in Damè-Wogon. Sometimes, when farmers are completely desperate, they have been known to commit suicide.

Labour shortage as a major constraint to weed management

In traditional farming, hand weeding is the most widespread weed management strategy. It is performed either by family members, hired labour or mutual support of self-help groups (*Adjolu*). Hand weeding is a stressful and tedious farm activity. With it, physical and psychological suffering enters the discourse of weeds. With the establishment of the National Society for Rural Development[2] (SONADER) in 1968, hired labour was sought for the instalment of the state oil palm plantations. This has given rise in weeding costs. The introduction of cash crops resulted in disintegration of the traditional social organisation and rising labour costs. In the 1970s, ridging 400m^2 cost 100F CFA[3]. Nowadays, labour for that area costs 1000 FCFA, 800 FCFA and 600 FCFA for land clearing, land preparation, and weeding respectively. Similarly, in the past, in Somè, farmers were organised in self-help groups that performed activities on members' farms. The monetary remuneration of labour was introduced with the introduction of cotton in the 1950s. Labour cost has risen from 1 FCFA in the past to 50 FCFA presently for preparing a ridge of 20 m length.

Nowadays, labour cost for weeding is determined by the following criteria: (1) invasion of perennial weeds (*Imperata, Cyperus*), (2) soil texture and workability, (3) presence of stumps, and (4) abundance of annual weeds. Labourers are not paid per man-day, but based on the time spent in the field. Labourers work for four hours (from 7 AM to 11 AM). Tables 2 and 3 present current labour prices per weed species and farm operation in Damè-Wogon and Somè, respectively. Weeding is more expensive than land preparation for the most troublesome weeds such as *Imperata cylindrica* and *Cyperus* spp. This is due to the fact weeding is less attractive than land preparation, because it consumes more time, is more tedious and stressful. People willing to perform weeding take advantage of this circumstance and demand higher prices plus food and drink. Sometimes labourers go to other farmers because they offer better prices for the job even if they had been appointed and their food had been cooked.

Speargrass requires the highest amount of financial investment, but these costs are higher in Damè-Wogon than in Somè. This difference is due to the fact that in Somè farmers prepare land and weed superficially and do not remove speargrass rhizomes.

[2] SONADER was a state body in charge of oil palm (*Elaeis guineensis*) plantations.

[3] 1 € =650 F CFA

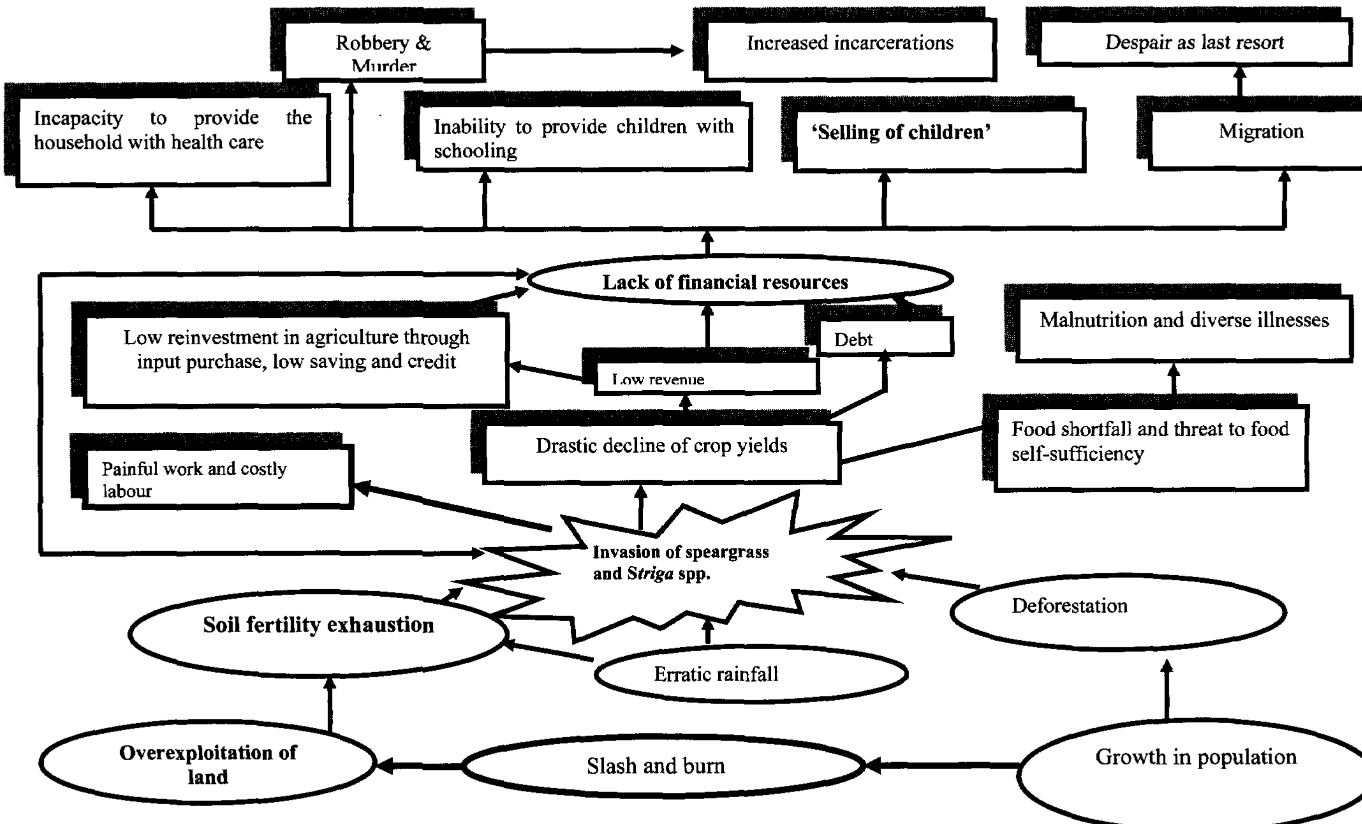

Figure 1 Farmers' perception of causes and consequences of speargrass and *Striga* problems (Weed problem tree as explained by the experimental groups of farmers in Damè-Wogon and Somè.)

Gender division of labour

We examined how gender affects the reaction to weeds emergence by analysing the division of labour. Land insecurity prevents women, who do not inherit land but have access to it according to traditional arrangements, from adopting soil and weed management technologies. Moreover, although women have access to land through their husbands, they are often given more exhausted and highly weed-infested land. Women usually help their husband in his field, which delays weeding their own field. Therefore, women suffer more than men from weed problems.

An investigation carried out on labour organisation and allocation within households reveals that men, women and children are involved in land clearing, land preparation and weeding (Table 4). The difference lies in the time spent to perform these different farm activities. Women spend more time than men and children's labour is essential. The same observations concerning women and weeds were made in the humid forest zone of Cameroon (IITA, 1995). Because they perform the bulk of weeding activities, women should be involved in the development of weed management strategies.

Table 2. Cost and amount of labour relative to land preparation and weeding of different types of weeds in Damè-Wogon

Weed species	Round of weeding	Labour (day /ha)		Cost (F CFA/ha)	
		Ploughing	Weeding	Ploughing	Weeding
Imperata cylindrica	3	125	125	125,000	262,500
Cyperus Spp	2	25	25	12,500	20,000
Commelina benghalensis	2	25	25	12,500	20,000
Oryza longistaminata	2	25	25	25,000	20,000
Panicum maximum	2	13	13	25,000	20,000
Centrosema pubescens	2	25	13	12,500	20,000
Andropogon gayanus	2	13	13	12,500	20,000
Cyperus sphacelatus	2	125	125	125,000	262,500

Source: Field interviews March 2005

Table 3. Cost and amount of labour relative to land preparation and weeding of different types of weeds in Somè

Weed species	Rounds of weeding	Labour (day /ha)		Cost (F CFA/ha)	
		Land preparation	Weeding	Land preparation	Weeding
Tridax procumbens	2	13	13	12,500	20,000
Panicum maximum	2	13	13	17,500	20,000
Cyperus spp.	2	13	13	12,500	20,000
Dactyloctenium aegyptium	2	13	13	12,500	20,000
Pennisetum polystachion	2	25	13	12,500	20,000
Pennisetum spp	2	25	13	12,500	20,000
Imperata cylindrica	3	125	125	112,500	187,500
Striga spp	3	13	13	12,500	30,000

Source: Field interviews March 2005

Table 4. Division of labour for speargrass management among farm operations according to gender and age in Damè-Wogon.

Activities	Level of involvement		
	Men	Women	Children
	Time spent[1] (hours/ha)	Time spent[1] (hours/ha)	Time spent[1] (hours/ha)
Land clearing	62.5-100	62.5-112.5	2.5-112.5
Ploughing	400	800	300-800
Weeding	600	800-1000	500-1000

Source: Field interviews 2005

History of the recognition of weeds as a problem by the authorities

Agricultural constraints during the pre-colonial era: 1800-1905

Archival research showed that pre-colonial era was essentially characterised by subsistence agriculture whereby large production units called *tatas* (large households composed of many families) were responsible for producing the bulk of food. Traditional rulers who headed these production units shared the produce among their people after sending the tribute payment to the king. Apart from cash crops, such as oil palm, coconut and tobacco, which were introduced by the king of Danxomè[4], Ghézo (1818-1858), food crops were prioritised, especially after the famine of 1847-1848 caused by a prolonged drought. The major agricultural problems mentioned were weed management and bush fires in oil palm plantations. No weed species were reported. Food crop cultivation was compulsory and the planting of oil palm was subject to strict regulation. According to colonial administration reports, herbaceous weeds were not a constraint in food crop production, although they were in tree plantations. These industrial crops were newly introduced and local farmers therefore lacked knowledge of their ecology. Abandoned plantations were highly susceptible to fire during the dry season due to severe weed infestation.

Agricultural constraints during the colonial era: 1906-1960

After King Béhanzin had been captured and the revolt of the Bariba people had been suppressed, the French colony imposed an agricultural policy that prioritised cash crops to the detriment of food crops. The agricultural sector was organised in marketing chains or commodity networks including agricultural research, credit, and extension (Savariau, 1906).

Research stations were initially managed by the French administration. French research institutes (e.g., *Office de la Recherche Scientifique et Technique dans les Territoires d'Outre-Mer*, ORSTOM) took over their management and more research stations were created. These included research stations on oil palm located at Pobè and on coconut situated at Sèmè created in 1922 by ORSTOM. In 1930, the experimental farm established at Ina (run by the *Institut Français de Recherches Agricoles Tropicales et de Cultures Vivrières*, IRAT) was created and specialised in animal traction and the pre-multiplication of seeds. The *Institut de Recherche du Coton et des Textiles Exotiques* (IRCT) for cotton and other textiles was created in 1947 (INRAB, 2005).

The research agenda emphasised yield improvement, and priority was given to varietal breeding, which extensionists could recommend to farmers. Other socio-economic and cultural aspects were overlooked. The general agricultural constraints included climatic constraints,

[4] Danxomè is the name of the Abomey kingdom, which has been changed to Dahomey (atual Republic of Benin) and attributed to the country after the independence by thr French colony.

difficulties in managing the indigenous Societies of Providence[5] (*Société Indigène de Prévoyance*: SIP), and distrust by farmers towards the technical packages introduced by the colonialists.

Speargrass invasion was cited as a major constraint for the first time in 1936. Weed management in coffee plantations was reported in 1945. A general report mentioned that "weed infestation in the coffee plantations was of concern in a number of centres despite all efforts made. Some farmers were very careless and seemed completely reluctant to heed the extensionists' advice" (Anonymous, 1949). The report also revealed that the number of weed-infested coffee plantations were smaller than the number of plantations that were frequently weeded. Specifically, 25% of the plantations were completely abandoned, 10% were neglected but regularly harvested, while 65% of the plantations were weeded well. In November 1954, the use of cover crops (*Pueraria javanica, Calopogonium mucunoides* and *Centrosema plumieri*) to restore soil fertility of oil palm plantations and of arable fields for food production was suggested. These cover crops would have helped control weed in these plantations. Hand weeding was still the main weed control method during that period.

Agricultural constraints of the post-colonial era

The political change to independence that occurred in 1960 also resulted in a shift in the agricultural sector. The state priorities were to achieve food self-sufficiency, increase crop production, to expand export cash crops in order to provide foreign currency, and to produce raw materials required by the state industries. From 1960-1972, policy priorities in agriculture were still directed towards export crops. Lack of chemical fertilisers and beetle *(Oryctes* spp.) damages were major constraints to cotton and oil palm respectively. There were no specific weed control experiments in maize cropping at the Niaouli research station (IRAT, 1974). The Marxist-Leninist era started in 1972. The new leaders declared agriculture to be the basis of development and industry the motor of the economy. This view brought about changes resulting in the creation of new research units, still with a mandate on export crops. Research activities in coffee and cocoa were launched again. In Benin, the laboratory of crop protection, which comprises weed management, was only created in 1975. In 1977, so as to better coordinate research activities, the Benin Government decided to take charge of research stations and experiment centres, which had been run by the French institutes until that time.

From 1977 to 1987, the major agricultural constraints included low and unpredictable rainfall, the decline in soil organic matter due to intensified land use, land shortage, insect pests, diseases, and grain-eating birds. During that period, research programmes emphasised

[5] Indigenous Societies of Providence were the extension structures in charge of disseminating agricultural technologies during the colonial era.

breeding of high yielding, early-maturing and drought-resistant varieties, fertiliser application, crop husbandry, and crop protection. Weed problems were not a priority.

Response of formal agricultural research

The reaction of scientists to farmers' emerging weed problem

From Table 5, it can be noted that researchers overlooked weeds, compared to other production constraints. Only 1% of research topics were related to weeds, compared to 20 % to soil fertility and water management, and 18% and 51% to animal rearing and fisheries, and post-harvest technologies, respectively. Until 1981, there were no weed scientists in Benin. The *Faculté des Sciences Agronomiques* of the University of Abomey-Calavi trained the first weed scientist in 1982. International research centres such as ICRISAT, SAFGRAD, IITA, IFDC, etc. are also involved in developing weed management technologies for resource-poor farmers either directly or through soil fertility management (Akobundu, 1993; Ba, 1983; Carsky *et al.*, 2000; IITA, 1986, 1998; Musselman & Parker, 1983; Reneaud, 1983; SP-IPM, 2003; Weber *et al.*, 1995a).

Weed science emerged, not because weeds were considered important in the food crop systems, but because the government embarked on rice production, and a student was asked to study weed – rice competition (Ahissou, 1982). It was around 1985 that researchers started paying attention to weeds. Weed scientists were trained to better manage *Commelina benghalensis*, which causes substantial yield losses in cotton (Ahanchédé, 1994) and *Striga* spp. in cereal-based cropping systems (Gbèhounou, 1992, 1998). Researchers' contribution to *Striga* control includes the development of resistant cultivars, the use of N-fertiliser, and the rotation with trap crops. Breeding for resistance and tolerance has been the major thrust and sources of tolerance have been identified (Kim, 1988; Kim & Akintunde, 1989). Resistant sorghum varieties have been developed by ICRISAT and for cowpea by IITA/SAFGRAD. IITA scientists developed screening and selection techniques for *Striga* resistance (IITA, 1983). IITA-improved early maturing erect cowpea varieties, one with resistance to *S. gesnerioides*, and transplanting of seedlings (for sorghum and millet) were also recommended to farmers (Gbèhounou *et al.*, 2004; IITA, 1993, 1998; INRAB, 2000, 2002). Several legumes were evaluated together with maize for their combined effect on reducing the *Striga* seed bank in the soil in comparison with fallowing. Soybean and a fodder legume (*Aeschynomene histrix*) were found to reduce *S. hermonthica* seed levels in the soil (Berner *et al.*, 1995).

The magnitude of the *Striga* problem led to institutional developments where scientists at the national, regional and international levels through networks and workshops engaged in collaborative action on the Striga threat to define research strategies and approaches (Kim, 1991; Lagoke *et al.*, 1994; SP-IPM, 2003). Researchers recommended the implementation of

Table 5 Research and Development responsiveness to the articulation of weed problems: number of items where the topic is mentioned, based on 1906-1997

Period (years)	*Striga* spp	*Imperata. cylindrica*	*Commelina. benghalensis*	*Cypérus rotundus*	*Chromolaena. odorata*	Weed in general	Aquatic weed	Forestry and agro-forestry	Soil fertility and water management	Animal rearing and fishery	Post-harvest technology	Institutional development
1906-1947												
1948									30	50	546	149
1967								3	65	245		
1971		1							56		675	106
1974				1				5	46			
1977						1		6	49	206		
1979						2		4	55			
1981						2		2	60	349	1607	207
1984						3		5	65			
1985	3					3		5	108			
1986		1						10	159			
1987	2				1	5		8				
1988	2					2		11	154			
1989	6					4		5				
1990		1						15	176	457	905	52
1991	2	1			1	4		13	155			
1992			1			5		18	100			
1993	4		2		2	3	4	13	167			
1994	8	2	2			1	1	20	109			
1995	8							18	76			
1997-2001	10	1						68	30	189	509	60
Total of subjects	43	07	05	01	04	35	05	229	1660	1496	4242	574
Relative importance of each theme (%)	0.5	0.08	0.06	0.01	0.04	0,42	0,06	2,75	20	18,0	51,1	6,91
	1,17%							98,78%				

Source: INRAB, 1997

integrated systems of control comprising (1) the use of *Striga*-free planting material; (2) crop rotation with selected non-host cultivars efficacious in germinating *Striga* spp. seeds, and (3) host-plant resistance, host-seed treatments, transplanting and biological control to reduce the amount of *Striga* seeds in the soils (Berner *et al.*, 2003; IITA, 1998; INRAB, 2001; Zoschke & Quadranti, 2002).

However the majority of these research findings were only adopted to a limited extent by resource-poor farmers (IITA, 1993; Rao, 1985) because they did not fit in their socio-economic conditions. Taking advantage of the introduction of cover crops (*Mucuna utilis*) in 1986 by researchers to ameliorate degraded soils, participating farmers drew researchers' attention to the effectiveness of legumes in suppressing speargrass (IITA, 1994; Versteeg & Koudokpon, 1990). This discovery by farmers triggered a nation-wide dissemination of green manure cover crops by researchers, development projects and NGOs (Buckles *et al.*, 1998; Carsky *et al.*, 2000; Vissoh *et al.*, 1997, 1998). The farmers' main reason for using *Mucuna* spp. was to suppress speargrass (Versteeg *et al.*, 1998). However, after about a decade of usage, farmers became disillusioned when they realised that the subsidised dissemination of legume cover crops had hidden the inherent constraints to their adoption (e.g., farmers cannot eat the seeds, the crop occupies scarce land, and requires a great deal of painful work to be removed). Despite the huge amount of initial funding provided by donors and the publicity given to it by researchers and developers, *Mucuna* use in Benin has strongly declined.

Herbicides (Round Up) were also recommended to farmers as an alternative to hand weeding, but their adoption was constrained by their unavailability, their prohibitive cost, and low food crop prices. Chemical control is only practised in cotton production in response to labour shortage.

Conclusion

This study has examined the responses of different actors to an important but historically underrated event: the emergence of herbaceous weeds as a result of reduced fallow periods and land scarcity under population pressure. Weeds have become a significant player in the vicious circle of rural poverty. The weed problem cannot be seen in isolation from increasing scarcity of labour and land. Unattractive food prices discourage small-scale farmers from investing in soil fertility and weed management. Consequently, soil mining and weed invasion mutually reinforce their impact on rural poverty.

The article has examined the social construction and response by three major actors to the emergent weed problem. Farmers, who have to live from the results of their labour on the land, were of course the first to suffer the consequences, especially women farmers. But rural people have also actively engaged in developing technologies to combat weeds. The other actors we looked at were the authorities in pre-colonial, colonial and post-independence periods. The examination of the records revealed that, while weed problems were reported quite early on, the focus was mainly on plantation and export crops that were important for revenue collection. The impacts of weeds on the rural population and on food crop production were generally ignored until very recently. Concomitant with official oversight of weeds, there was an almost total neglect of weeds by agricultural research until well into the 1980s. Even then, spending on weed research has been very limited. We can only speculate on the reasons for this finding. One major reason could be that science has systematically overlooked the importance of labour in weeding. It is all too common to read in a research paper that "fields were weeded when necessary" without specifying who did the weeding and how much labour was involved. This oversight could also be related to gender bias because women are more engaged in weeding. Later on, when agricultural science did address issues of weed management, it was still partly blind to the constraints that farmers experience (costs of herbicides and fertilisers, time needed for weeding, the impossibility to use cover crops if that results in foregoing the harvest of an edible crop during a season, etc.).

Weeds are a key component of rural poverty in West Africa. Effective weed control methods should be key concern for agricultural research that seeks to reduce rural poverty in West Africa. Our study reveals how little weed perceptions and weeding practices by small-scale farmers influenced the research and policy agenda of agricultural science and the government. Perhaps the key lesson from this study is that different conceptualizations (constructions) of weeds determined different practices of weed management and that a conceptual convergence is essential for designing more effective pathways of science in future.

Chapter 5

Improving local technologies to manage speargrass (*Imperata cylindrica*) in southern Benin

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Submitted to *International Journal of Pest Management*

Improving local technologies to manage speargrass (*Imperata cylindrica*) in southern Benin

Abstract

Speargrass (*Imperata cylindrica*) is difficult to control in the tropics, and the Republic of Benin is no exception. Farmers allocate most of their time and labour to weeding speargrass. A joint experiment was set up with a group of farmers comprising 5 cowpea and 2 pigeonpea varieties. We investigated how effectively these legumes suppress speargrass, and how speargrass suppression is related to legume grain yield and the yield of a subsequent maize crop. We also tested whether fertiliser application to maize would be more profitable with more effective speargrass suppression. Without management, speargrass shoots and rhizomes increased with 31 and 17 percent per month respectively. Farmers' practices suppressed speargrass to some extent, but integration of deep ridging, deep hoe weeding and shading suppressed speargrass shoots and rhizomes more effectively. Creeping varieties of cowpea that produced most biomass were most successful in suppressing speargrass and in enhancing yields of subsequent maize crops, but erect cowpea cultivars produced more grain. Farmers' decision making gives first priority to high grain yield in cowpea to bridge the hungry gap, even though this is traded off against speargrass suppression and yields of a subsequent maize crop. Farmers' preference was for the erect cowpea cultivar *wan*. Fertiliser application was more successful in the case of effective speargrass suppression. The partial budget was three times higher in the cowpea system than that in the pigeonpea system. Even though late-maturing pigeonpea was more effective in suppressing speargrass, the need to forego a harvest and the fact that pigeonpea is not consumed in the area at present makes pigeonpea unsuitable for integration into the cropping system.

Keywords: permanent cropping, participatory approaches, grain legumes, Integrated Crop Management

Introduction

In shifting cultivation, the need for fallowing is often more a function of weed – crop competition and the amount of labour required to maintain crop yields, than of declining soil fertility. Nye & Greenland (1960) and Hairiah *et al.* (2000) hypothesised that a plot will be fallowed when the labour required to control weeds exceeds the labour needed to clear a new site. So it is the decreasing land / labour ratio that drives the shift towards continuous cropping, and even while continuous cropping without nutrient addition depletes the soil, the short-term effect is still beneficial.

In southern Benin, where more than 60% of the nation's population lives, a drastic shortening of fallow periods resulted in a strong pressure on land. Consequently soils are degrading and novel weed species, amongst which the pioneer species speargrass [*Imperata cylindrica* (L.) Raeuschel], invade (Vissoh *et al.*, 2006). Speargrass is a perennial rhizomatous grass weed found on all continents in the tropics and parts of the sub-tropics. It is particularly a problem in high rainfall areas of South-East Asia and West Africa (Anon., 1996; Akobundu, 1987; Akobundu & Agyakwa, 1987; Chikoye *et al.*, 2002; Holm *et al.*, 1977). In West Africa, speargrass is a major production constraint in plantations of oil palm, coconut, and rubber; and in food crops like cereals and root and tuber crops (Holm *et al.*, 1977; Vissoh *et al.*, 1998). Speargrass has a low nutrient demand, thriving on both infertile and fertile soils (Garrity *et al.*, 1997). It is also an effective competitor for light, nutrients, and water due to its extensive root systems. Moreover, it has allelopathic effects on crops such as maize, and interferes through physical penetration of roots and below-ground tissues of crops resulting in damage and subsequent rotting (Akobundu & Ekeleme, 2000; Chikoye, 2003; Eussen, 1978; Hairiah *et al.*, 2000; Lum *et al.*, 2005; MacDonald, 2004; Van Rijn, 2000). Once established, speargrass can survive almost indefinitely with frequent burning, with the species increasing the risk of fire (Anon., 1996).

Speargrass control is primarily a problem of labour. Hand labour required for the elimination of speargrass has been measured at 60 to 80 workdays ha^{-1} (Versteeg *et al.*, 1992). Hoeing a hectare takes 90 to 100 workdays of 7 to 8 hours a day (Anon., 1996), while digging out speargrass rhizomes requires 175 workdays ha^{-1} (Chikoye *et al.*, 2000; Vissoh *et al.*, 2004). Because of its rhizome-forming habit, speargrass cannot easily be eliminated by hand cultivation. The rhizomes are also not affected by that practice. Under such conditions, farmers are forced to weed more frequently. However, increasing labour expenditure for speargrass control is not particularly effective, given speargrass' propensity for rapid re-growth (Bagnall-Oakeley *et al.*, 1997). A 15 cm rhizome fragment can produce more than 350 shoots in six weeks (Anon., 1996) while Eussen (1978) reported the production of 350 shoots from rhizomes, covering an area of

4 m² in 11 weeks.

Uncontrolled or poorly controlled speargrass can result in severe crop yield losses. Complete crop failure usually occurs when crops are grown in slashed plots without additional weeding (Chikoye, 2003). In developing countries, legume cover crops and tree-based farming systems and to a lesser extent herbicides have been tested to reduce speargrass density (Akobundu *et al.*, 2000; Chikoye *et al.*, 2001; Hairiah *et al.*, 2000; MacDonald, 2004; Van Noordwijk *et al.*, 1997). Despite the effectiveness of green manure cover crops, small-scale farmers experience a number of disadvantages (Bagnall-Oakeley *et al.*, 1997; Chikoye, 2003; Deffo *et al.*, 2004; Vissoh *et al.*, 2004). The adoption of herbicides is generally low (Chikoye *et al.*, 1999; Chikoye *et al.*, 2000; Bouraima, 1986; Vissoh, 1994; Vissoh *et al.*, 2004). However, legumes that produce edible grains, while providing a dense canopy that suppresses speargrass, can be attractive to the majority of farmers and beneficial in terms of soil fertility improvement. Grain legumes that provide food and cash to farmers have a long history in West Africa (Oyewole *et al.*, 2000; Schulz *et al.*, 2003a). In southern Benin, cowpea is traditionally the main leguminous food crop for home consumption and cash.

The objective of this study was to contribute to land use systems that increase crop yields through the development of speargrass management strategies that are acceptable, feasible and work under farmers' conditions. More specifically, this study attempted to: (1) identify farmers' strategies to control speargrass, (2) assess the agronomic effectiveness of some grain legumes to suppress speargrass, produce acceptable grain yields and yields of subsequent crops, and improve soil fertility for permanent land use, (3) assess the socio-economic impact, and (4) determine farmers' perceptions about the feasibility and acceptability of these management strategies.

Materials and methods

Study area

A survey and experiments were conducted at Dame-Wogon (District of Bonou; 6°34' N, 2° 27'E), a village in southern Benin about 70 km northwest of Porto-Novo. The soil is sandy loam on the plateau and clayey in the bottom of the valley. The rainfall pattern is bimodal and has an annual range from 1000-1400 mm. Fallow periods nowadays do not exceed four years. In a diagnostic study in the area (Vissoh *et al.*, 2004), farmers ranked soil fertility second after rainfall, and weeds fourth after pests, as main constraints to agricultural production.

A survey was conducted in the five villages that constitute Damè-Wogon, using a structured questionnaire to identify the various speargrass management strategies used by farmers. At the same time, semi-structured interviews, participant observation, focus group discussion and informal interviews were conducted to make an inventory of farmers' strategies to manage speargrass. The questionnaire was administered to 50 farmers randomly selected in the different villages of Damè-Wogon. Both male and female respondents were selected. Fields were visited for observation and to crosscheck quantitative and qualitative data collected during the survey, and the group and informal discussions.

Speargrass management strategies

Farmers reclaim speargrass-infested plots using a legume-maize rotation. According to farmers, cowpea is used for three main objectives: (1) to provide food, especially in the hungry season, (2) to cover the soil and thereby suppress speargrass, and (3) to improve soil fertility, which increases subsequent maize yield. Just before the onset of the major rainy season, farmers slash and burn speargrass. After a week, they prepare the land by ridging, and sow cowpea. Speargrass management includes hilling or ridging. Cowpea variety choice is based on various criteria: maturation time (farmers prefer early-maturing varieties), habit (a dense canopy suppresses speargrass much better), vegetative biomass production (improves soil fertility for the subsequent maize crops), grain production, grain price on the market, taste, cooking time, and the possibility to use it to perform ritual ceremonies. Farmers' preference is for cultivar *wan*, which is an early-maturing, erect and leafy cultivar.

Experimental design

An experiment was designed in 2004 during the major rainy season with a group of farmers in a randomised complete block design with four replications. Nine treatments were tested, including a control without speargrass management, farmers' practice, and 7 legume cultivars under improved speargrass management. Farmers' practice consisted of superficial ridging (about 10-15 cm), sowing of cowpea (the local cultivar *wan*) and superficial hoe-weeding. The improved practice consisted of deep ridging and deep hoe-weeding (about 20-40 cm) after determining the depth of the rhizomes underground, and sowing of grain legumes at sufficiently high density to shade speargrass. Crops comprised five cowpea cultivars including three erect, early-maturing, and two creeping, late-maturing cultivars, and two pigeonpea cultivars (early-maturing and late-maturing). Table 1 presents the different treatments as well as the characteristics of the different grain legumes used.

Each elementary plot measured 5 m x 5.5 m. After thinning, two plants per hill were left for all grain legumes. Cowpea grains were harvested and the leaf biomass was incorporated into the soil (ridging). Maize [Downy Mildew Resistant Early Streak Resistant and White (DMR-ESRW)] was sown during the minor rainy season in a split plot design with four replications. Half of each plot received a fertiliser application at the rate of 100 kg ha^{-1} NPK 15 days after sowing, and 50 kg ha^{-1} urea at tasselling. Plots with late-maturing pigeonpea could not be cropped with maize during the second rainy season, because it is a long-duration crop. In order to compare pigeonpea varieties, plots with the early-maturing cultivar were not cropped with maize as well.

Maize was also sown in 2005 during the major rainy season. All plots except the control were ridged and sown with maize at a space of 0.8 m x 0.4 m with two seeds per hill in a split plot design with four replications. Fertilisers were applied to one half of each plot similarly to 2004. During the second rainy season, the same legume species were planted again on the same plots for two major reasons: (1) continuation of speargrass suppression to prevent rapid re-infestation because remaining viable rhizome fragments could grow into new speargrass shoots, (2) improving soil organic matter and nitrogen content to allow a permanent land use system.

Table 1. Characteristics of grain legumes used

Cowpea varieties	Growth cycle (days)	Vegetative habit	Spacing adopted by farmers'	Increased density
Control	-	-		-
Farmers' practice	80	erect and leafy	0.8 m x 0.5 m	0.8 m x 0.4 m
Wan	80	erect and leafy	0.8 m x 0.5 m	0.8 m x 0.4 m
Assissihunkpo	75	erect	0.8 m x 0.5 m	0.8 m x 0.4 m
Azobahundé	75	erect	0.8 m x 0.5 m	0.8 m x 0.4 m
Atakpra	110-115	creeping	0.8 m x 0.8 m	0.8 m x 0.5 m
Délékinwa	100-110	creeping	0.8 m x 0.8 m	0.8 m x 0.5 m
Pigeon pea varieties				
Late maturing pigeon pea	360	branchy and bushy	1 m x 1 m	0.8 m x 0.8 m
Early maturing pigeon pea	90	erect	0.8 m x 0.8 m	0.8 m x 0.4 m

Data collection

The number of speargrass shoots was determined four times (before the set up of the experiment, before deep weeding, at cowpea harvest, and at maize harvest) from two subplots measuring 0.25 m^2 each per elementary plot. These subplots were dug out three times (before ridging, at cowpea harvest, and at maize harvest) and rhizomes collected. Rhizome dry weight was determined after oven drying at 70°C for 48 hours. Because initial speargrass density differed somewhat between plots (the control plots had a significantly lower number of shoots compared to other treatments at the start of the experiment), changes in shoot number and rhizome biomass are reported.

In 2004, at cowpea harvest leaf dry weight produced by each legume was assessed from two subplots of 0.25 m^2 after oven drying at 70°C for 48 hours. Legume pods were harvested for yield determination from the two subplots of each plot measuring 6 m^2 leaving out plants on the borders. Legume grains were dried and adjusted to moisture content of 14%. Maize cobs were harvested in December from the two central rows measuring 7.4 m^2 of each subplot for yield determination. Maize grain yield was adjusted to moisture content of 12%.

Individual farmers who participated in the experiment were asked to rank the different grain legumes based on their general performance (yield, speargrass suppression, subsequent maize yield, marketability, etc.).

Partial economic budgets

Costs and benefits for all treatments were determined using partial budgets (Alimi & Manyong, 2000; Brown, 1979). Only the variable costs, *i.e.*, costs that varied among technologies, were considered. These variable costs were subtracted from the gross benefits to obtain net benefits. The marginal costs and the marginal net benefits were calculated to finally determine the marginal rate of return of the improved speargrass management practices compared to farmers' traditional practices. The marginal rate of return was determined for both *wan* and for late-maturing pigeonpea. In both cases, the partial budget was determined over three growing seasons (including one season with legumes and two seasons with maize).

Data analysis

Analysis of variance (ANOVA) was carried out on the agronomic data using Statistical Analysis Systems (SAS, 1999) based on the experimental designs (randomised complete block and split plots designs). Means were compared using the Student-Newman-Keuls (SNK) test. Change of speargrass shoots and rhizomes were calculated as fractional decrease / increase per month. Correlations were calculated between cowpea biomass, cowpea grain, speargrass suppression (shoots and rhizomes), and the yield of a subsequent maize crop. A logarithmic transformation [log (x+1)], where x is the number of shoots or rhizome dry weight, was undertaken to ensure normal distribution and for stabilising the variance between treatments.

Results and Discussion

Speargrass management strategies used by farmers and improved practices

Almost all farmers (94%) applied some strategies for speargrass management. These strategies are integrated control options rather than a single practice. Their strategy comprises slashing, burning, ridging, and rotating cowpea with maize. Burning facilitates ridging and hastens the sprouting of new speargrass shoots which are bent by ridging and susceptible to decay. Interviewed farmers stated that ridging turns the soil, which breaks and brings rhizomes to the soil surface in the furrows, where they dry under the sun and subsequently decay under rainfall. Farmers also reported that cowpea residues incorporated to the soil improve soil fertility, thereby increasing maize yield.

A guide for improved management of speargrass at farm level was jointly developed with participating farmers through discovery learning in 2003 (Fig. 1). Compared to farmers' practices, this new set of practices includes deep ridging taking into account depth where rhizomes are found; sowing of cowpea or pigeonpea cultivars at higher density (Table 1) to shade speargrass shoots as long as possible; deep hoe-weeding; hand pulling whenever necessary; treatment of cowpea plants to prevent leaf damage caused by defoliating insects; and deep ridging by incorporating cowpea residues into the soil. The scheme was evaluated with farmers at the end of the experiential learning phase. The effectiveness of this scheme depends on the time during which speargrass is shaded. Therefore, the set of practices should be repeated the following year, if a farmer judges that speargrass shoots are not sufficiently suppressed. Compared to the first rainy season, cowpea cultivars did not perform well during the second rainy season to effectively suppress speargrass. The bottleneck, which may constrain adoption of these integrated practices, is labour shortage. The integrated practice is three times as labour demanding as farmers' practices. Farmers stated that even though labourers received a great deal of money, as well as food and drink, deep ridging was not properly done unless the farmer involved himself in this operation to set a good example. Women reported they were cheated by labourers who did not ridge deeply as expected. The same happened with deep hoe-weeding.

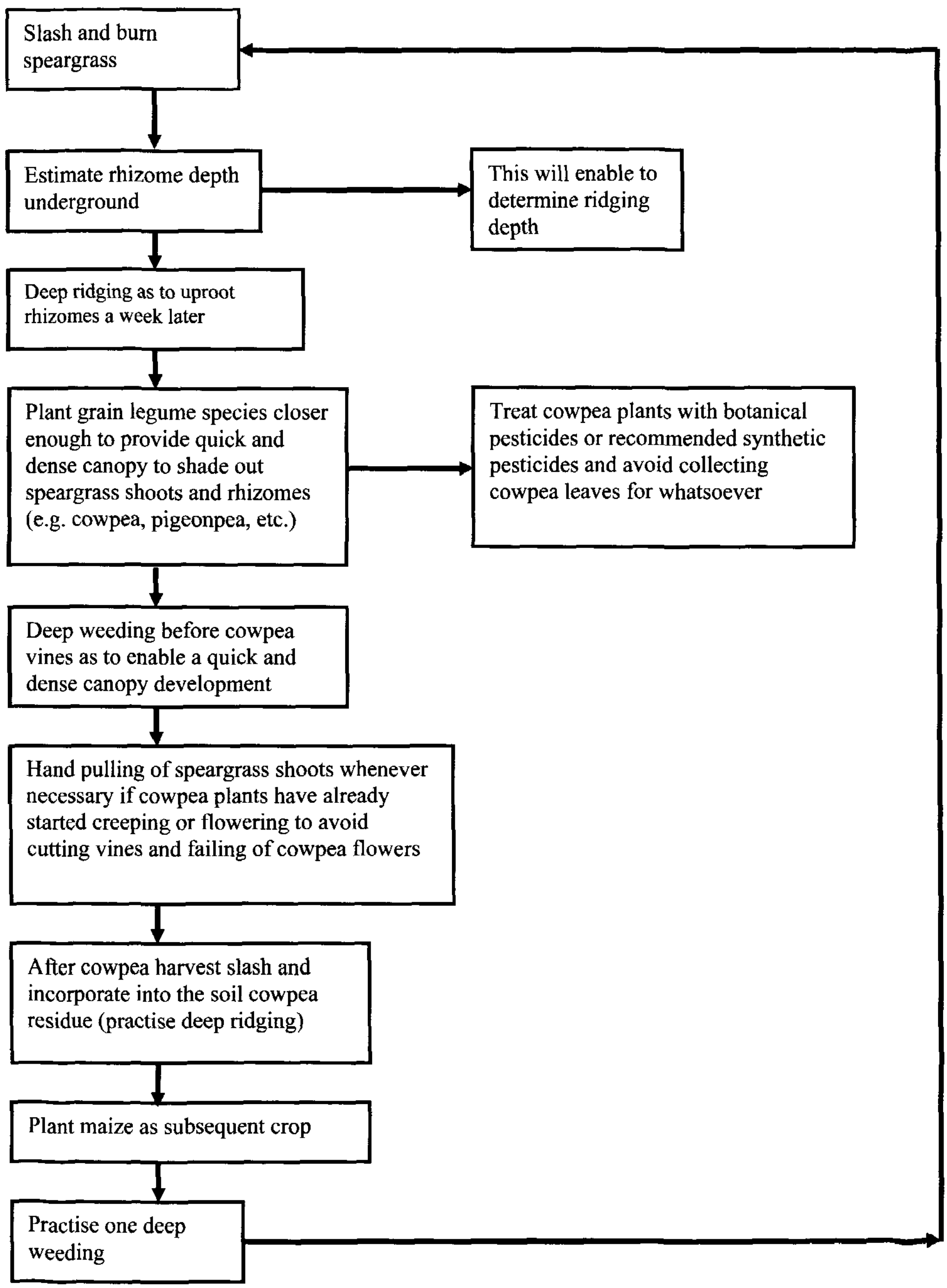

Figure 1. A Guide of speargrass management for permanent land use.

Speargrass dynamics

Changes in shoot number and rhizome dry weight were estimated over the whole experimental period in 2004 (from the start to maize harvest). Monthly rates of change are presented in Table 2. Changes in shoot numbers and rhizome biomass were very significantly correlated ($r = 0.96$, $n = 9$; $P < 0.001$). Without management, speargrass shoots and rhizome biomass increased with 31 and 17% per month respectively. All management practices led to a decline in speargrass shoots and roots. Farmers' practice was least effective. The improved practices were significantly better than farmers' practices for all cowpea cultivars (except rhizome biomass with the cowpea variety *azobahundé*) and for late-maturing pigeonpea. Early-maturing pigeonpea was not significantly different from farmers' practices. With cowpea cultivars, late-maturing, creeping varieties suppressed speargrass better than early-maturing, erect varieties, especially with regard to rhizome biomass. The main difference between erect and creeping growth forms is the rate at which the soil is covered and shaded. The effectiveness of shading to suppress speargrass is well documented (Anoka *et al.*, 1991; Terry *et al.*, 1997; Chikoye & Ekeleme, 2003; Chikoye *et al.*, 2005; Ekeleme *et al.*, 2003; Van Noordwijk *et al.*, 1997; MacDonald, 2004). The local variety *wan* was equally effective as the other erect varieties in reducing speargrass shoots, but significantly outperformed the other erect varieties in reducing rhizome biomass. Late-maturing pigeonpea performed best of all legumes. Pigeonpea was earlier shown to be able to successfully suppress speargrass (Hairiah *et al.*, 2000; Chikoye & Ekeleme, 2001). The canopy of the early-maturing pigeonpea, which only partly suppressed speargrass, was neither dense nor complete (Table 2).

Chikoye & Ekeleme (2001), Chikoye *et al.* (2000) and Terry *et al.* (1997) noted that cultivation can be beneficial in exposing rhizomes to desiccation but that it also can stimulate bud growth by fragmentation of the rhizomes and by aeration of the soil. In our experiment, new shoots were excavated during deep hoe-weeding before legumes sufficiently covered the soil. Speargrass rhizomes were observed at more than 50cm below-ground at the start of the experiment. This depth was substantially reduced in plots in which speargrass suppression was more effective, especially with late-maturing pigeonpea. In fact, in this field the following year (2005) superficial ridging and hoe-weeding sufficed, whereas deep ridging and deep hoe-weeding were still necessary on cowpea plots.

Table 2. Monthly rate of change of speargrass shoots and rhizome dry matter in 2004

Treatments	Change in shoot number per month (%)	Change in rhizome dry weight per month (%)
Control	31 ± 2 a	17 ± 3 a
Farmers' practice	-11 ± 1 b	-12 ± 1 b
Wan	-27 ± 3 c	-27 ± 2 d
Assissihunkpo	-26 ± 3 c	-23 ± 1 c
Azobahunde	-27 ± 1 c	-17 ± 1 b
Atakpra	-34 ± 3 d	-32 ± 2 d
Delékinwa	-30 ± 2 c	-32 ± 3 d
L MC. *cajan*	-36 ± 3 d	-40 ± 4 e
E MC. *cajan*	-12 ± 1 b	-14 ± 1 b
Probability	0.0001	0.0001

Means followed by a common letter in the same column are not significantly different ($P > .05$) using the Student-Newman-Keuls test

Cowpea biomass production and grain yield

Farmers judge grain legumes not only because of their suppressive effect on speargrass. Direct effects (legume grain yield) and carry-over effects on a subsequent cereal crop (due to nitrogen fixation and organic matter addition after its leaf residues are incorporated in the soil) need to be assessed together with speargrass suppression. Those direct yield effects make grain legumes different from green manure cover crops like *Mucuna,* which have been rejected by small-scale farmers because they do not provide a direct return on their investment (Bagnall-Oakeley *et al.*, 1997; Chikoye, 2003; Vissoh *et al.*, 1998).

A comparison of the cowpea cultivars under improved management showed that cowpea cultivars producing most leafy biomass were most effective in suppressing speargrass rhizomes (Fig. 2). The relationship was highly significant ($r = -0.78$, $n = 20$, $P < 0.001$). The relationship between cowpea leafy biomass and suppression of speargrass shoots was marginally significant ($0.05 < P < 0.1$), suggesting that shading affect rhizomes more than shoots (Table 3).

Biomass of the various cowpea cultivars was significantly negatively correlated with cowpea grain yield ($r = -0.66$, $n = 20$, $P < 0.01$; Fig. 3). Because cowpea leaf biomass correlated positively with speargrass suppression, cowpea grain yield correlated negatively with speargrass suppression (Table 3). Farmers therefore have to face a trade off between cowpea grain yield for home consumption and / or sale (which is highest in erect, early-maturing cultivars) and speargrass suppression (which is highest in creeping, late-maturing cultivars). This general trade off between high harvest index of grain legumes and subsequent soil fertility enhancing effects (Vanlauwe & Giller, 2006) does not always occur. In a comparison of five cowpea cultivars in the forest / savannah transitional zone in Ghana, Adjei-Nsiah *et al.* (2006) reported that a late-maturing, creeping, leafy cowpea cultivar, yielded both highest amount of leaf litter and the highest amount of grains.

The need to overcome the hungry period, when food reserves run low, compels farmers to choose early-maturing cowpea varieties, which are less effective in suppressing speargrass. The use of late-maturing cowpea cultivars (e.g. *atakpra and délékinwa*) is too risky; if sown early, the cultivars may perish because of drought spells, but if sown late, farmers may be prevented from cultivating maize, a staple food crop during the second rainy season. During the second rainy season of 2005, both cowpea and pigeonpea cultivars did not grow well (data not shown) due to insufficient rainfall. Farmers acknowledged that cowpea cultivars do not usually perform well during the second rainy season.

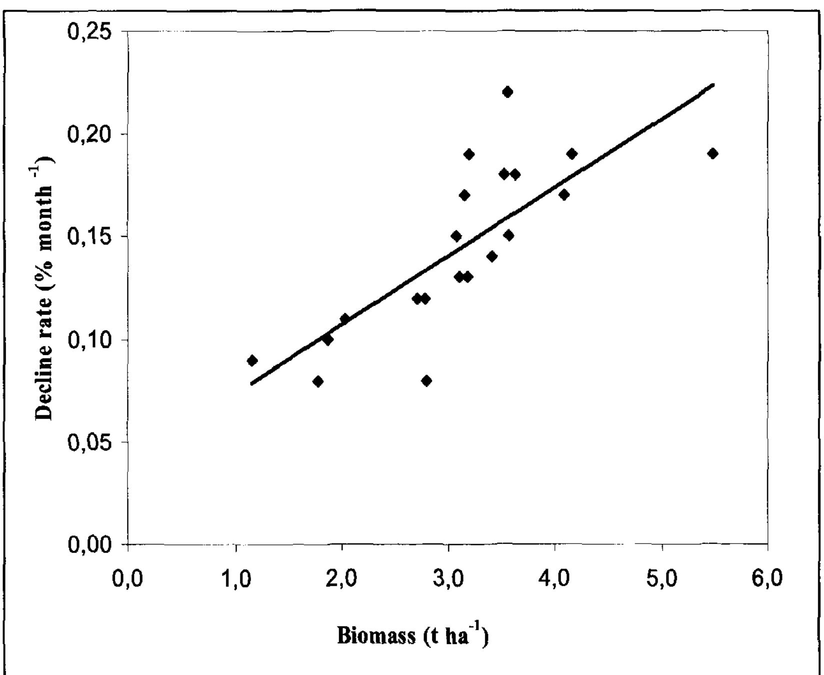

Figure 2. Relation between cowpea biomass and monthly decline rate of rhizome dry weight

Table 3. Correlation between variables

Variables	N	**Cowpea leaf biomass**	**Cowpea grain yield**
		R	
Speargrass shoot change	20	-0.41 ns	0.66**
Speargrass rhizome change	20	-0.78***	0.79***
Cowpea gain yield	20	-0.66**	-
Maize yield	20	0.79***	-0.78***
Maize yield after fertiliser	20	0.75***	-0.65**

Significance: n.s. not significant; ** $0.001<P<0.01$; *** $P<0.001$.

Maize yield

Maize yield in 2004 and 2005 was significantly affected by application of different cowpea residues (Table 4). Incorporation of residues of creeping cowpea cultivars resulted in significantly higher maize yields than incorporation of residues of erect cultivars. Simultaneously, less speargrass shoots reappeared in plots in which residues of creeping cowpea cultivars had been incorporated. Rhizome dry weight followed the same pattern. In all cases, the cultivar *wan* outperformed the other erect cowpea cultivars, both in enhancing maize yield and in suppressing speargrass.

In subsistence agriculture, small-scale farmers hardly use chemical fertiliser because they lack resources or they do not have easily access to fertiliser, unless they are cotton growers. As part of this experiment we included a treatment of fertiliser, in order to assess whether fertiliser use would be more profitable under conditions of more effective speargrass suppression. Without fertiliser maize yields ranged from 0.90 to 1.70 t ha^{-1} in 2004, and between 1.01 and 1.81 t ha^{-1} in 2005, and with fertiliser between 1.36 and 2.26 t ha^{-1} in 2004, and between 1.50 and 2.43 t ha^{-1} in 2005. Fertiliser use on average increased maize yields with 0.53 t ha^{-1} in 2004 and 0.61 t ha^{-1} in 2005. There was no significant interaction between cowpea cultivar and fertiliser treatment (Table 4). The fertiliser effect ($P < 0.001$) indicates that it could be to farmers' advantage to apply a minimum amount of fertiliser after incorporating cowpea residue into the soil if opportunities exist (e.g., fertiliser is available, which is often not the case; farmers have money to buy fertiliser; or credit schemes exist). The economical amount of fertiliser to be applied needs to be determined in further studies. These aspects will be discussed later when analysing the partial budget.

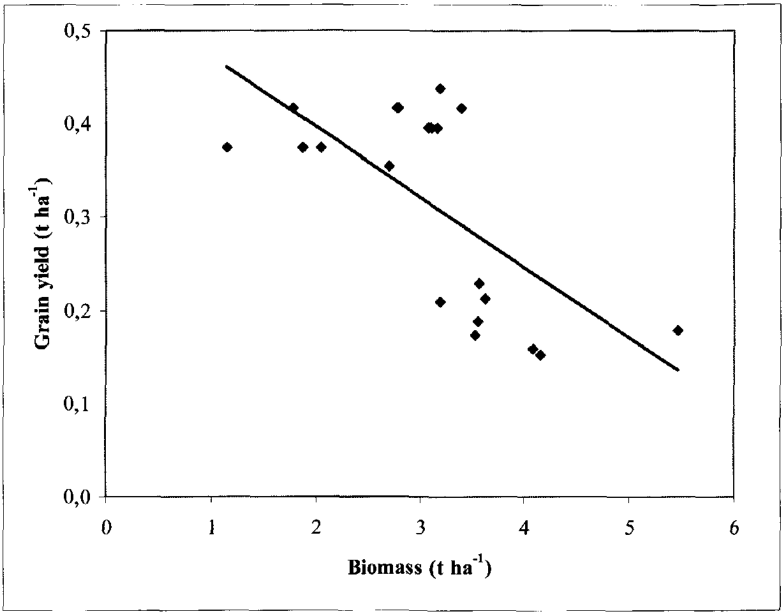

Figure 3. Relationship between cowpea biomass and cowpea yield

There was a significantly positive correlation ($r = 0.79$, $n = 20$, $P < 0.001$) between grain legume biomass and maize yields. Because legume biomass was negatively correlated with legume grain yield, maize yield was also negatively correlated with cowpea grain yield ($r = -0.78$, $n = 20$, $P < 0.001$) (Table 3, Fig. 4). Again, farmers have to face the trade off between cowpea grain yield for home consumption or sale on the one hand, and the effects of leafy legumes (speargrass suppression, soil fertility enhancement resulting in higher cereal yield). The same trends were also observed when fertilisers were applied to maize. Cowpea biomass was positively correlated with maize yield ($r = 0.75$, $n = 20$, $P < 0.001$) and cowpea grain yield was negatively correlated with maize yield ($r = -0.65$, $n = 20$, $P<0.01$).

Table 4. Response of maize to grain legume residue and fertiliser application, and shoot abundance and rhizome dry weight of speargrass.

Treatments	N	Degree of freedom	Years		Number of Shoots	Rhizome dry weight
			2004	2005		
Wan	8		1.56 ± 0.13 c	1.76 ± 0.15 b	3.79 ± 0.32 c	6.44 ± 1.12 c
Assissihunkpo	8		1.31 ± 0.12 d	1.46 ± 0.10 c	4.56 ± 0.24 b	12.15 ± 2.16 b
Azobahundé	8		1.13 ± 0.10 e	1.25 ± 0.11 d	5.59 ± 0.20 a	21.54 ± 2.61 a
Atakpra	8		1.98 ± 0.12 a	2.12 ± 0.12 a	2.63 ± 0.23 d	4.24 ± 0.68 c
Délékinwa	8		1.77 ± 0.10 b	1.87 ± 0.16 b	2.63 ± 0.23 d	3.77 ± 0.59 c
Probability			0.0001***	0.0001***	0.0001***	0.0001***
CV (%)			10.20	10.91	17.68	40.74
			F value			
Variety		4	36.88***	27.04***	28.43***	28.83***
Fertiliser		1	113.94***	109.22***	8.61**	0.50 n.s
Variety*fertiliser		4	0.62 n.s	0.81n.s	0.29 n.s	0.01

Values that are followed by a different letter in a column indicate significant differences between treatment at $P<0.05$ with Student-Newman-Keuls test.
Significance of ANOVA: n.s. not significant; ** $0.001<P<0.01$; *** $P<0.001$.

Farmers' perceptions and preferences for the different legume cultivars

Farmers were asked to rank the five cowpea cultivars and the two pigeonpea cultivars. Results are given in Table 5. Farmers' ranking is not only determined by the effects that the various cultivars have on speargrass suppression, legume grain yield, and yield of subsequent maize crops (properties that have already to be traded off), but also by socio-economic factors (market prices, food quality, labour). Farmers ranked the erect cultivar *wan* as the most preferred cultivar.

This results supports the suggestion by Giller (2001; see also Adjei-Nsiah *et al.*, 2006) that soil fertility benefits of legumes are better regarded as additional benefits than as primary criterion for legume selection. Should *wan* be not available, farmers prefer creeping, late-maturing cultivars (which are more effective in increasing maize yields and suppressing speargrass) over the other erect, early-maturing cultivars.

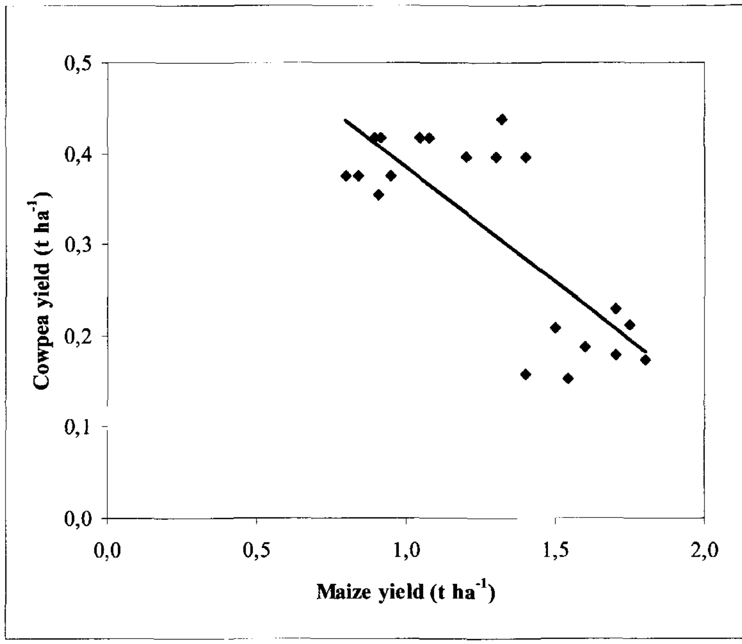

Figure 4. Relationship between maize and cowpea yields

Cowpea variety *wan* is widespread in the study area while the creeping cultivars *atakpra* and *delekinwa* are alien to the study area, even though they are cultivated in the surroundings. Furthermore, the variety *wan* is a short duration crop (about 80 days), which fits in the prevailing cropping system while the other varieties are long-duration (more than 100 days). Shorter maturing cowpea varieties (60 to 75 days) such as *assissihunkpo* and *azobahundé* are not only rather ineffective in suppressing speargrass, but also their market prices are not attractive to farmers compared that of *wan*. They are also not easy to sell because they are not tasty and more susceptible to insect pests.

Table 5. Farmers' perception on the acceptability and farmer' use of different legume cultivars, 17 farmers were interviewed

Cowpea variety	Ranking	Farmers' Perceptions
Wan	1	Impressive biomass, complete canopy, good yield, early maturing, improves soil fertility, increases maize yield, attractive market price, fast to cook and sell, tasty
Atakpra	2	Late maturing, complete canopy, impressive biomass, good yield, improves soil fertility, increases maize, no outlet, lack of seeds
Délékinwa	3	Late maturing, complete canopy, impressive biomass, good yield, improves soil fertility, increases maize, no outlet, lack of seeds
Assissihunkpo	4	Poor biomass, good yield, incomplete canopy, low market price not fast to sell
Azobahundé	5	Early maturing, no good yield, incomplete canopy, susceptible to insect pest (storage), low market price, not fast to sell
Pigeonpea varieties		
Late Maturing pigeonpea	1	Controls speargrass in one year, improves soil fertility and increases maize yield, not susceptible to insect pests, long duration crop, not appropriate to small-scale farmers, lack of seeds, lack of market, not tasty, takes time to be cooked, not used for ritual ceremonies
Early Maturing pigeonpea	2	Short duration, poor biomass, not effective in controlling speargrass, not tasty, takes time to be cooked, not used for ritual ceremonies, lack of seeds, lack of market

Farmers' decision making (*wan* as most preferred cowpea cultivar) includes a further element. The degree to which cowpea cultivars suppress speargrass, produce leafy biomass and produce grains, is dependent on planting density. With higher planting densities, cowpea becomes more effective as suppressor of speargrass but this will result in lower grain yields. By varying planting density farmers could then also trade off cowpea grain yield against the other beneficial aspects of the legume.

Almost all farmers, except one, preferred late-maturing pigeonpea variety (about 10 months) to the early-maturing variety (3 months). The single farmer who preferred early-maturing pigeonpea owned a plot in the bottom valley of the Ouéme River. For him the need to harvest it before the flooding period, which occurs every year around August, is paramount. Farmers preferred cowpea to pigeonpea for a number of reasons. First of all, pigeonpea as a long-duration crop does not fit in the cropping system where land is a limiting factor to food crop production. Second, apart from sparse use of pigeonpea as a medicinal plant, this crop is not cultivated in the area. It is not even sold in the market. Having tasted pigeonpea meals (both the late- and early-maturing cultivars), which participating women cooked, 90% of the farmers stated that it was not tasty; more than 50% complained about stomach ache, while the women who cooked the meal reported that it consumed too much time and firewood, both scarce items in this environment. Finally, farmers reported that pigeonpea is not used for ritual ceremonies. Hinvi *et al.* (1991) made the same observation for the Atlantique department.

Economic analysis of speargrass management

The fundamental difference between farmer's practice to manage speargrass and that of the improved integrated strategy is that ridging and hoe-weeding are deeply practised in such a way as to reach the depth at which rhizomes are found below-ground. It is a laborious and costly activity, three times as costly as farmers' practice.

In order to understand whether this additional investment is worthwhile, partial budgets were set up, and marginal benefits of improved practices with cowpea (*wan*) and late-maturing pigeonpea were compared to farmers' practices with *wan* (Table 6). Partial budgets can of course give partially misleading results, and some qualifications are in order. Provided that a farmer possesses the required financial resources, the budget assumes that -- labour and fertiliser can be acquired for these prices. While this assumption is true for labour (at least in a formal sense – labourers do not always perform according to what is expected from them, see above), it is almost certainly not the case for fertiliser. Farmers are constrained in acquisition of fertiliser, because it is often not available, except in areas with large scale is cotton-growing. Furthermore labour and fertiliser have to be paid in advance, while the benefits can be reaped only after the harvest, leading to cash flow problems.

So even if an investment is advantageous, farmers could still be constrained in making it. Finally, the partial budget takes into account variable costs between farmers' practice and improved control methods over three rainy seasons (first and second rainy seasons of 2004 and first rainy season of 2005).

That choice for three seasons may be another issue in the budget that should not be accepted without qualification. Such short-term budgets inevitably lead to the consequence that

Table 6. Partial budget for cowpea and maize production of different speargrass control methods (farmers' and improved methods).

	Speargrass control method		
	Farmers' practice	Improved control method	
Gross product	Cowpea variety "wan"	Cowpea variety "wan"	LM Pigeonpea
1-Mean cowpea yield in 2004 (kg ha^{-1})	248	401	-
2- Mean maize yield in 2004 (kg ha^{-1})	940	1880	-
3-Mean maize yield in 2005 (kg ha^{-1})	1035	2127	2860
4- Cowpea selling price (FCFA kg^{-1})	350	350	-
5- Maize selling price (FCFA kg^{-1})	500	500	500
6- Mean pigeonpea yield (kg ha^{-1})			330
7- Pigeonpea selling price (FCFA kg^{-1})			350
8- Gross product (FCFA ha^{-1}) for two years	=1*4 + (2+3)*5 1,074,300	1*4 + (2+3)*5 2,143,850	2*5 + 6*7 1,545,500
Variable costs FCFA ha^{-1}			
9- Ridging (for cowpea and maize /pigeon pea) (3 growing seasons)	60,000[1]	187500[2]	62,500 + 20000=82,500
10- Weeding and/or manual hand pulling (cowpea and maize) (2 major and one minor rainy seasons)	60,000[3]	187500[4]	46875 +15000=61,875
11-Cowpea treatment (*Hyptis suaveolens* aqueous extract + pesticides)	30,000	30,000	-
12-Mowing of cowpea residue and pigeonpea plants	12,500	12,500	25,000
13- Fertiliser application	75,000	75,000	37,500
14 – Total of variable costs	237,500	492,.500	206,875
(14)- Net benefits (8 – 14)	836,800	1,651,350	1,338,625
Marginal costs		255,000	285,625
Marginal net benefits		814,550	312,725
Marginal rate of return (%)		319	109

[1] =20.000*3 seasons
[2] =62.500*3
[3] =15.000*2*2
[4] =46.875*4

continuous cropping, even when this leads to nutrient depletion and diminishing harvests, has a more positive budget than a cropping system where fallowing is included (as in late-maturing pigeonpea). The conclusion that continuous cropping is advantageous from a short-term perspective was also drawn by Samaké (2003). Average market prices for the products were taken into account for the calculation of the gross products. Price differences for the various cowpea cultivars have not yet been considered. Even though pigeonpea is not consumed by the farmers in Dame-Wogon, there is still a market for pigeonpea in the neighbourhood, but that market may be rapidly saturated.

Both partial budgets were positive, indicating that improved speargrass management does pay off. The marginal rate of return for the cowpea system was three times higher than for pigeonpea (Table 6). This difference was due to the fact that a total of 4 t of maize was produced by the cowpea system in two harvests while the pigeonpea system resulted in almost 3 t in one harvest. Furthermore, cowpea yield was higher than that of pigeonpea (Table 6). It appears that the pigeonpea system is more effective in suppressing speargrass than the cowpea system, but economically (at least in this partial budget approach) the cowpea system performs better.

From this partial budget, the use of fertilisers depends not only on their availability, but more importantly on the maize price. This supposes that the subsequent maize price is attractive, which is not always the case due to price fluctuations. Lack of control over market prices by farmers, resulting in falling prices with increased production, will make the use of fertilisers hardly attractive. Another bottleneck is labour availability and labour cost. In this regard, the adoption of the improved speargrass management technology will be constrained unless farmers have financial resources, or have access to credit or belong to any social organisation (e.g., social help group).

Conclusion

This experiment has enabled farmers to value their knowledge, initiative and creativity in the field of integrated crop management and especially integrated weed management. Joint experimentation enabled them to change their cultural practices and to adopt more effective strategies. Speargrass problems became worse during land intensification (a consequence of shorter fallow periods). This novel weed problem necessitated novel weed management, such as suppression through legumes. Including legumes in the cropping system led to a further evolution towards permanent cropping systems in order to prevent re-infestation. To some extent, permanent land use could solve the problem of acute land shortage – as long as the fertility of that land is sufficient. This then enforces the need for including legumes in the cropping system. But effective speargrass management also imposes a number of trade offs that farmers need to make between speargrass suppression, cowpea grain yield and subsequent maize yield through soil fertility improvement.

Different legumes occupy different niches in such cropping systems and these niches are defined by biological, socio-economic and cultural dimensions. In order for a legume to successfully occupy (or construct, *cf.* Day *et al.*, 2003) a niche in cropping systems where speargrass is a major problem, the legume must allow permanent land use. For instance, pigeonpea, despite its effectiveness to effectively control speargrass and increase nitrogen status of the soil, seems to have less chance of being adopted by farmers than cowpea cultivars. In a sense pigeonpea is too much like the old green manure cover crops such as mucuna. That conclusion may seem dependent on the present evaluation that pigeonpea is unsuitable as a food crop. One may wonder whether there is a possibility to increase the local uses for pigeonpea. But even under those conditions it would almost certainly remain true that a legume, which forces farmers to forego one cereal harvest, is unacceptable to them under conditions of permanent land use.

Intermezzo[1]

Striga song

Welcome white men
Here in Somè, Do[2] threatens our survival
For many years, our efforts to combat Do were fruitless
When we crop maize, our staple food, we harvest nothing
When we cultivate sorghum, our staple food, we harvest nothing
When we plant cowpea, we hardly harvest
A snake catches a frog; God will send somebody to save us
God sent Mr Vissoh through white men to learn with us how to cultivate maize, sorghum and cowpea
Welcome white men, it is king of you
Changing cultural practices for maize, sorghum and cowpea
Do that threatens our livelihoods
We must understand its biology and adopt appropriate and effective technology
Changing maize cropping
Changing sorghum cropping
Changing cowpea cropping
Changing, changing, changing
From now we have changed our cultural practices.

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[1] The intermezzo records the text of a song that was sung by the farmers on the occasion of a field visit by the supervisory team with the Dutch supervisors.

[2] In the local language Fon, Do refers to death. The word is used for both the symptoms of crop failure, due to *Striga*, and for the causal agent of this failure. In that case Do can be translated with *Striga*.

Chapter 6

Evaluation of integrated crop management strategies to cope with *Striga* infestation in permanent land use systems in southern Benin

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Submitted to *International Journal of Pest Management*

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Abstract

The parasitic plants *Striga hermonthica* and *S.gesnerioides* pose serious threats to cereal and cowpea production endangering people's livelihoods on the Abomey plateau. A two-year joint experiment was undertaken with two groups of farmers in two hamlets of Somè village to investigate the potential of sowing dates of cowpea varieties, sorghum transplanting, and trap cropping as ways of reducing *Striga* damage and increasing agricultural production. Joint learning enabled farmers to recognise the host specificity of both *Striga* species and to understand the life cycle of the parasite. Early sowing of cowpea cultivars doubled yield compared to late sowing and reduced numbers of *S. gesnerioides*. Transplanting of sorghum nearly doubled or tripled cereal yield and substantially reduced *S. hermonthica* infestation compared to direct early sown sorghum. Although sorghum transplanting required additional labour; the increase in yield compared to direct sowing was an incentive that motivated farmers to its adoption. Trap crops such as cowpea, groundnut, bambaranut, and soybean grown in rotation and intercropped with maize increased subsequent maize yield and reduced *S. hermonthica* infestation. All experiments yielded significantly different results between both hamlets and indicated that farmers in Somè central were confronted with much poorer soils than farmers in Assiankpa. The very poor soils in Somè central were a major constraint to farmers to improve their yields to acceptable levels even after the introduction of these new crop (and *Striga*) management methods. Despite narrow windows of opportunities in both villages, farmers through a Farmer Field School can be empowered to adopt integrated crop management in order to cope with *Striga* and to improve their livelihoods.

Keywords: Soil fertility decline, *Striga* infestation, crop losses, participatory learning, integrated crop management

Introduction

In many parts of the Guinea Savannah of West Africa, intensification of traditional cropping systems led to continuous cropping of cereals and unsustainable cropping practices, resulting in depletion of organic matter and plant nutrients (SP-IPM, 2003). Consequently, crops grew less vigorously and problems with parasitic weeds (especially species of the genus *Striga* (Orobanchaceae)) became more serious (Berner *et al.*, 1995; Oswald, 2005; SP-IPM, 2003). The most common and devastating *Striga* species in the savannah zone is *S. hermonthica* (Del.) Benth., a parasite of millet (*Pennisetum americanum* (L.) K. Schum.), sorghum (*Sorghum bicolor* (L.) Moench), maize (*Zea mays* L.), rice (*Oryza sativa* L.) and sugarcane (*Saccharum officinarum* L.) (Dembélé *et al.*, 1994; Lagoke *et al.*, 1991). Moreover, *S. gesnerioides* (Willd.) Vatke constitutes a major biotic threat to cowpea (*Vigna unguiculata* (L.) Walp.) (Dubé & Olivier, 2001; Lane *et al.*, 1994). Cowpea is usually grown in rotation or intercropped with cereals (maize, sorghum and millet) and in such cropping systems both *S. hermonthica* and *S. gesnerioides* infest the same plot, compounding the *Striga* problem on smallholdings.

Striga species are among the most important constraints to agricultural development in Africa (Arnaud *et al.*, 1999; Berner *et al.*, 2003; Emechebe *et al.*, 2004; Sauerborn, 1991; SP-IPM, 2003). *Striga* negatively affects the lives of over 100 million African people. The value of total annual crop loss in Africa has been estimated at 7 billion US Dollars (Kureh *et al.*, 2000). *Striga* species cause estimated yield losses ranging from 10 to 95 percent, depending on ecological conditions and agronomic practices (Lagoke, 1998). In some areas, parasitism by *Striga* causes complete crop failure, and farmers are forced to abandon heavily infested fields in search of *Striga*-free plots (Lagoke *et al.*, 1991; Lagoke, 1998; Vissoh *et al.*, 2004). The areas badly affected by *Striga* are also the areas where many of the poorest people live with the highest percentage of cereals in their diet (Kanampiu *et al.*, 2002). Resource-poor farmers, who constitute 80 percent of the farming population, have often insufficient resources such as land and financial means to purchase agricultural inputs. Consequently, their *Striga* management technologies are rather ineffective (Lagoke, 1998; Vissoh *et al.*, 2006). Furthermore, these *Striga*-affected areas are also severely affected by other abiotic (low and erratic rainfall, low soil fertility) and biotic (other pests and diseases) constraints (Lagoke, 1998). *Striga* is therefore best regarded a symptom of a complex of factors that cause poor soil quality, and trying to control it separately from integrated soil and crop management will only have a limited effect. Ransom (2000) stressed that *Striga* control should not be dealt with in isolation because soil fertility is itself an immense constraint to cereal production in Africa.

Intensive research on *Striga* control has been carried since the last two decades in Africa; nevertheless, the *Striga* problem not only has persisted but has increased (Kroschel, 1999;

Oswald, 2005). Kanampiu *et al.* (2002) argued that research recommendations are not what farmers consider appropriate for their needs of providing sufficient food for their families on small, intensively cultivated holdings. Previous research efforts were confined to the development of single components for *Striga* control, usually based on the researcher's perception and discipline, rather than integrated in a multidisciplinary basis (Lagoke, 1998; Richards, 1985). Consequently, technologies for controlling *S. hermonthica* have not been widely adopted as many control components did not fit within the farming practices (Lagoke, 1998; Lendzemo & Kuyper, 2001). Various low-cost and practical *Striga* control alternatives at farm level have been reported to reduce the initial stock of *Striga* seed bank, improve soil fertility and increase yields of subsequent crops (Berner *et al.*, 1995; Carsky *et al.*, 2000; Gbèhounou *et al.*, 2004; Oswald *et al.*, 2002; Schulz *et al.*, 2003b; Weber *et al.*, 1995b). The potential of short-duration planted fallows and fast growing legume trees as a potential means to replenish soil fertility and reduce *Striga* infestation were demonstrated by Gacheru & Rao (2001, 2005). However, acute land shortage and the prevailing land tenure systems often constrain farmers' adoption. Adoption of strategies that work is also limited by the fact that farmer's knowledge of the biology of *Striga* species (specificity, life cycle, production of minute seeds, seed dispersal, persistence of seed banks, main damage while the parasite is still in the subterranean stage, etc.) is incomplete or insufficient. It is therefore important to develop or improve *Striga* control measures with the active participation of farmers in order to arrive at methods that are effective, work and are acceptable under their socio-economic conditions.

The objective of this study was to contribute to the development or improvement of effective *Striga* control practices in southern Benin. Specifically it aimed to (1) identify *Striga* control measures (or management practices that affect *Striga*) developed and/or adapted by small-scale farmers in the study area, (2) evaluate the control measures developed by farmers and / or proposed by science in terms of crop yield and *Striga* control, (3) assess farmers' perception of the feasibility and acceptability of the improved *Striga* control measures in the framework of their cropping practices.

Materials and Methods

Study area

Surveys and experiments were conducted at Somè located in the district of Za-Kpota (7° 13'N, 2°12'E). Two hamlets, differing in pressure on the land and in their cropping history, were chosen. At the central hamlet of Somè, plots used for experimentation have been permanently cropped for the last thirty years without external inputs. In Assiankpa there was a history of permanent cropping for 15 years. Besides, prior to the present study with farmers, plots in

Assiankpa were used for four years by INRAB (*Institut National des Recherches Agricoles du Bénin*) researchers for participatory management of *S. hermonthica*. These trials included maize response to different rates of inorganic fertilisers (Flatin, 2003).

In the past, the district of Za-kpota was endowed with abundant land. The bulk of the food consumed in the kingdom of Danxomè was produced in this area. Traditional rulers who headed the production units were in charge of sharing agricultural products after sending the king's share (tribute payment). In that time slaves were usually sent to work in the plantations for the king who benefited from their remuneration. In recent decades, rapid population growth has resulted in acute land shortage, more permanent and intensive land cultivation, and severe invasion of *Striga*. The new generation does not have access to land, forcing young people to leave agriculture for off-farm activities (Vissoh *et al.*, 2006). Nowadays, the vestige of the former slave society is still being manifested through the practice of entrusting children and emigration of young men, which has exacerbated labour scarcity.

Average annual rainfall follows a bimodal pattern and ranged between 972-1103 mm from 2000-2005. However, there is a suggestion that climatic change is reducing the amount of rainfall. Data suggest that at the onset of the rainy season rainfall is less predictable (which equals a shift in the effective start of the cropping season from Mid-March to April), that the number of rainy days are going down (and the number of dry days between rains are increasing), and that the rainfall use efficiency of crops has gone down (Hein & De Ridder, 2006). Early planting with the first rains often suffers early drought spells resulting in the need for second or third planting when rains are established (Weber *et al.*, 1995b). Soils are ferralitic and classified as Nitisols (FAO/UNESCO, 1990; Raunet, 1977). Farmers ranked first rainfall, second soil fertility, and third weeds, especially *Striga* species, as main constraints to agricultural production (Vissoh *et al.*, 2004). Cultivated plots are usually infested by both *S. hermonthica* (on cereals) and *S. gesnerioides* (on cowpea). Farmers, however, do not separate both species.

Investigation of Striga spp. management strategies

A survey was conducted in 2002 in Somè central and Assiankpa, using a structured and a semi-structured questionnaire, focus group discussions and informal interviews to inventory the various *Striga* control strategies. These strategies include farmers' own practices and adapted research recommendations. The questionnaire was administered to 50 farmers randomly selected in each of the two hamlets. Both male and female respondents were interviewed. Different farmer categories were selected for the semi-structured interview. These categories comprised old, middle-aged, and young men, and women. Triangulation was used to ascertain the reliability of data collected. Fields were visited using participant observation to crosscheck quantitative and qualitative data collected during survey, group and informal discussions.

Farmers' practices identified during the diagnostic study (Vissoh *et al.*, 204) included planting dates of early maturing varieties (allowing crops to escape *Striga* in time because *Striga* seeds need conditioning before they can germinate and attach), crop rotation and/or intercropping (grain legumes (cowpea, groundnut and bambara groundnut) and several other plants are trap crops for *S. hermonthica*), and sorghum transplanting. Sorghum transplanting was not practised to control *S. hermonthica* but farmers acknowledged that transplanted sorghum not only out-yielded directly sown sorghum, but also reduced *Striga* emergence. These strategies were selected with farmers for joint experimentation. An assessment of integration of *Striga* control methods was adopted in a two-year experiment within a context of permanent land cropping systems. Table 1 presents crop succession per growing season from 2003 to 2005.

Assessment of sowing dates of cowpea varieties as *S. gesnerioides* control method

Planting early cowpea varieties just at the onset of the rainy season could be a strategy to reduce *S. gesnerioides* infestation. Early planting tries to profit from the small window of opportunity between too early sowing (and having a drought risk at the start of the rainy season), too late sowing (and having the risk that cowpea cannot complete its life cycle), and sowing more or less in the optimal rainfall period but then having the larger *Striga* risk.

Table 1. Sequence of experiments with farmers.

Years	2003*		2004		2005	
	Major rainy season	Minor rainy season	Major rainy season	Minor rainy season	Major rainy season	Minor rainy season
Planting dates	Testing of sowing dates of local cowpea varieties	-	Planting dates of cowpea varieties	Intercropping maize-grain legumes (trap crops)	Planting dates of cowpea varieties	Intercropping maize-grain legumes (trap crops)
Sorghum transplanting	Sorghum transplanting (getting insight into farmers' practices) Rotation with cassava		Sorghum transplanting		Sorghum transplanting	

* Learning from farmers' practices (experiments neither replicated nor randomised and therefore not reported in this chapter)

Two different cowpea varieties were planted in each hamlet during the first rainy season. The varieties included a local variety chosen by farmers and an improved resistant variety (TVX – 1850-01F) suggested by the researcher. They are both early maturing varieties (less than three months duration). Three planting dates were tested, spaced out 10 days.

A four-factorial experiment including: hamlet (Somè central vs Assiankpa), year (2004 vs 2005), cowpea variety, and planting dates was set up in a randomised complete block design with four replications. The experimental plots measured each 48 m^2 (6 m x 8 m). Plants were spaced 0.75 m between rows and 0.4 m with two plants per hole. Plants were sprayed three times 20, 35 and 50 days after sowing using a recommended insecticide (*Orthen* – the organophosphate acephate).

Transplanting of sorghum

A local late-maturing variety of sorghum (more than six months) was used. A three-factorial experiment including hamlet, year, and various nursery or transplantation treatments was set up in a randomised complete block design with four replications. The following types of nursery beds were set up:

1. farmers' traditional methods of setting up nursery bed on ridges (put more seed/hole and thin for transplanting;
2. farmers' traditional methods of setting up nursery bed in furrows;
3. nursery bed enriched with organic matter (on household refuge heaps) ;
4. nursery bed enriched with mineral fertiliser (application of 70g of NPK per hill containing about 10 seedlings);
5. nursery bed installed on (moderately) fertile, *Striga*-free plots (on remote outfields)
6. direct sowing of sorghum the same day nursery beds were set up (control plot)
7. direct late sowing of sorghum the same day sorghum seedlings were transplanted.

After approximately four weeks sorghum seedlings were supposed to be transplanted but due to a drought spell the transplanting dates were delayed two to three weeks. In central Somè, due to land shortage, each plot measured 30 m^2 (6 m x 5 m) and sorghum seedlings were spaced out 0.75 m between rows and 2 m along rows and two plants per hole. For uniformity, the direct sown sorghum was thinned to two plants per hill, even though farmers use more than ten plants per hill. In Assiankpa the same spacings were adopted but the plot was a bit larger (6 m x 8 m).

Trap cropping as a *S. hermonthica* control measure

Five different grain legume taxa comprising: two cowpea varieties (used for the planting dates experiment), a local groundnut variety, (*Arachis hypogea* (L.)), soybean (*Glycine max* (L.)

Merrill cv. Jupiter), and a local variety of Bambaranut (*Vigna subterranea* (L.)Verdc.) were planted in a randomised complete block design with four replications. As control an improved maize variety (DMR ESRW) was used. Each of the grain legumes was intercropped with maize. A three-factorial (hamlet, year, plant taxon) experiment was set up in a randomised complete block design with four replications during the second rainy season. This trial was carried out on the same plots where the previous cowpea experiment was conducted because of the permanent land use system. All crops were sown at 0.75 m between rows. Cowpea was spaced 0.4 m along the rows and two plants per hill. Soybean was sown at 0.3 m along rows and two plants per hill, and groundnut and Bambaranut were sown at 0.2 m along the rows and two plants per hill. Maize was planted 0.4 m and two plants per hill in the control and at 1.5 m along rows with two plants per hill while intercropped.

Data collection and analysis

Cowpea pods were harvested for yield determination from two quadrats per plot each measuring 9 m^2 (3 m x 3 m). Cowpea grains were sun-dried and adjusted to 14% moisture content. *Striga gesnerioides* shoots were counted weekly in 9 m^2 (3 m x 3 m) plots. In central Somè hamlet, *Striga* counts took place 65, 75 and 90 days after early planting of cowpea. In Assiankpa hamlet, *Striga* shoots were counted at 51, 58, 65, 70, and 89 days after early planting.

Grain yield was estimated from two quadrats of each plot measuring 6.25 m^2 (2.5 m x 2.5 m) at central Somè and 9 m^2 (3 m x 3 m) at Assiankpa. The numbers of sorghum plants, where panicles did not set grains. were counted. *Striga hermonthica* was counted 8 and 9 weeks after direct sowing of sorghum in central Somè hamlet and Assiankpa respectively.

Maize yield per plant was determined in the trap crop experiment. Both *S. hermonthica* and *S. gesnerioides* plants were counted from two quadrats of each plot measuring 9 m^2 (3 m x 3 m).

A three-way and four-way analyses of variance (ANOVA) were carried out on the agronomic data using Statistical Analysis Systems (SAS, 1999) based on the experimental designs (randomised complete block design). Means were compared using Student-Newman-Keuls (SNK) test. A log transformation [log (x+1)], where x is the number of *Striga* shoots, was undertaken to meet the ANOVA assumptions.

Results and Discussion

Striga spp. management practices used by farmers in Somè

Strictly speaking, farmers do not apply *Striga* management strategies. They resort to various strategies to manage their cropping system and these strategies also affect *Striga* species. For that reason we will discuss the effect of management practices on the crop before discussing the effects of these practices on *Striga*. Ninety percent of the farmers use one or more strategies that affect *Striga*. Most farmers apply more than one strategy simultaneously. Early sowing is often part of such strategy, and it is applied by 66 % of the farmers interviewed. Early sowing (and the use of early-maturing varieties) of cowpea and sorghum is used first and foremost to shorten the hungry period at the end of the dry season. Farmers realised that early sowing of cowpea varieties also affected *S. gesnerioides* abundance. Hand pulling of *Striga* was practiced by only 4% of the interviewed respondents. Farmers stated that hand pulling is labour intensive and time consuming, and that it does not provide immediate returns because *Striga* inflicts most its damage to their hosts before emerging. Twenty percent of the farmers used inorganic or organic fertilisers including poultry manure, household refuse, or a mix of both sources. Fertilisers are primarily used to increase crop production, but farmers are aware that the increased soil fertility also reduces *Striga*. However, organic manure (compost) is only seldomly available. Farmers consider compost application time consuming and labour intensive, due to the large amount recommended per unit area. While there is often a lack of animal (poultry, livestock) manure, application of mineral fertiliser is beyond the financial means of Somè farmers. Ten percent of the farmers did not apply any management against *Striga*.

Sorghum transplanting was widespread with 94% of the interviewed farmers practising at least one of the types identified. A low number of farmers (6%) did not transplant sorghum because of labour scarcity. The majority of the farmers (86%) transplanted sorghum using thinned seedlings. Transplanting sorghum from established nursery beds, which is much more time-consuming, was practised by 8% of the farmers.

Cowpea - *Striga gesnerioides* management

The results of the four-way ANOVA are presented in Table 2. Cowpea yield was significantly affected by hamlet and sowing date. Cowpea yield was significantly lower in Somè central than in Assiankpa. Later sowing reduced cowpea yield. This difference could be due to the fact that intermediate and late sowing suffered water shortage at the end of the growth cycle due to insufficient rainfall (Alonge *et al.*, 2005; Dubé & Olivier, 2001). Planting took place in May when rains were more or less established. There was no really early planting (mid March) of cowpea cultivars. This was due to the delay in the start of the rainy season forcing farmers, who had sown in mid March to sow cowpea twice. The three-way interaction hamlet x year x cowpea cultivar was also significant.

Abundance of *S. gesnerioides* was significantly affected by hamlet and cowpea cultivar. Much more *S. gesnerioides* emerged in Somè central than in Assiakpa. More *Striga* plants emerged on the local cultivar than on the improved resistant cultivar, but this did not result in cowpea yield differences. The two-way interaction sowing date x cowpea cultivar, and the three-way interaction hamlet x year x cowpea cultivar were also significant. Sowing dates did not significantly affect the number of *S. gesnerioides* plants that emerged. This latter result was not surprising because there was no really early planting of cowpea cultivars. We assume that, once rainfall is sufficiently regular, the difference of 10 days that elapsed between two consecutive sowing dates was not sufficient to induce differences of *Striga* infestation. Under conditions of more predictable rainfall at the start of the rainy season, early sowing of cowpea reduces *Striga* infestation and enables crops to grow vigorously before conditions are favourable to the parasite (Dembélé *et al.*, 1994; Dubé & Olivier, 2001; Sauerborn, 1991; Touré *et al.*, 1996).

These results indicate that farmers have to trade off the risk of insufficient rainfall and *Striga* infestation. Both early sowing (before *Striga* seeds are conditioned) and late sowing (when conditioned *Striga* seeds turn into secondary dormancy because of a lack of a suitable host) are risky, as farmers may either have to sow twice (in the case of too early sowing) or cowpea plants cannot complete their life cycle (in the case of too late sowing). The vagaries of the climate therefore seem to allow no alternative but cowpea sowing at the time when the risk of *Striga* infestation is highest. Especially the farmers in Somè central, where the very poor soils result in a low rainfall use efficiency by the crops, seem to have no choice but to synchronise the cycle of cowpea and its parasite. Under such situations, one may doubt whether improved cropping practices and *Striga* management alone are enough to escape from their constraints.

Sorghum transplanting as means to control *S. hermonthica*

Results of the three-way ANOVA are presented in Table 3. Sorghum yield was significantly affected by hamlet, year, and nursery or transplantation treatment. The hamlet x year interaction was also significant. Sorghum yield was significantly higher in Assiankpa than in Somè central. Application of mineral fertiliser or organic amendment resulted in the highest sorghum yields, whereas direct late sowing and sowing in nursery beds in furrows resulted in very low yields. These results are in agreement with previous studies carried out on sorghum transplanting (Berner *et al.*, 1995; CAZS, 2003; Elzein & Kroschel, 2003; Gbèhounou *et al.*, 2004). Transplanted sorghum from nursery beds enriched with mineral fertilisers and organic matter were better able to resist *Striga*-induced stress.

Table 2. Effect of the main factors (hamlet, year, cowpea cultivar, and sowing data) on cowpea grain yield (kg ha^{-1}) and number of *S. gesnerioides* emerged (9 m^2). The results of the 4-way ANOVA are given in the lower part of the table.

Main factors		**Cowpea yield (kg ha^{-1})**	**Emerged *Striga gesnerioides* (9 m^2)**
Central Somè		291 ± 14a	1.44 ± 0.09a (93.2)
Assiankpa		362 ± 18b	0.30 ± 0.06b (9.0)
2004		337 ± 18a	0.81 ± 0.09a (45.1)
2005		316 ± 15a	0.92 ± 0.10a (57.1)
local cultivar		311 ± 17a	1.03 ± 0.10a (64.4)
improved cultivar		341 ± 16a	0.71 ± 0.09b (37.8)
Early sowing		389 ± 18a	0.94 ± 0.12 a (54.7)
Intermediate sowing		321 ± 23b	0.83 ± 0.11 a (34.4)
Late sowing		269 ± 16b	0.83 ± 0.12 a (64.3)
Source of variation	**df**	**F value**	
Hamlet	1	10.99***	125.79***
Year	1	0.93 n.s	1.07 n.s
Cultivar	1	1.93 n.s	9.68**
Sowing date	2	10.26***	0.57 n.s
Hamlet x year	1	0.18 n.s	2.27 n.s
Hamlet x cultivar	1	0.05 n.s	0.46 n.s
Hamlet x sowing date	2	0.62 n.s	0.41 n.s
Year x cultivar	1	0.73 n.s	0.06 n.s
Year x sowing date	2	1.11 n.s	0.11 n.s
Cultivar x sowing date	2	0.86 n.s	6.01**
Year x hamlet x cultivar	1	4.13*	6.36*
Year x hamlet x date	2	0.11 n.s	2.07 n.s
Hamlet x cultivar x date	2	0.09 n.s	0.23 n.s
Year x cultivar x date	2	0.04 n.s	0.61 n.s
Hamlet x year x cultivar x date	2	0.43 n.s	0.47 n.s

Numbers in brackets have been subjected to logarithmic transformation. Values that are followed by a different letter in a column indicate significant differences between treatment at P<0.05 with Student-Newman-Keuls test. ± indicates standard error. Significance of ANOVA: n.s. not significant; *0.01<*P*<0.05; ** 0.001<*P*<0.01; *** *P*<0.001.

Plants that are challenged to *Striga* at a later stage possess a certain physiological tolerance to the effects exerted by the parasite (Berner *et al.* 1995; Oswald *et al.*, 2001). Van Ast *et al.* (2005) postulated that for yield reduction, the moment of first *Striga* infection might be at least as important as the number of infections. This conclusion fits with our observation as seedlings from the early direct sowing treatment were already infested when seedlings raised for transplanting were still in the nurseries. The extremely low sorghum yield produced by delayed direct sowing was due to insufficient rainfall after delayed sowing, in combination with the low rainfall use efficiency in such degraded plots. Despite a reduced *Striga* infestation, late direct sowing is not an appropriate *Striga* control measure to be recommended to farmers as also noted by Gbèhounou *et al.* (2004). Seedlings raised in the furrows did not grow well for two major reasons (1) unfertile nursery bed as the top layer soil was removed during ridging, (2) intermittent dry spells that retarded seedling growth.

The percentage of sorghum plants bearing no seeds followed more or less the same patterns: significant effects by hamlet, year and nursery or transplantation treatment, and significant hamlet x year and hamlet x treatment interactions. In plots with direct late sowing and in plots where in nursery beds in furrows was sown almost all sorghum plants did not bear fruit.

Emergence of *S. hermonthica* was also significantly affected by hamlet, year, and treatment, and the hamlet x year, and hamlet x treatment interaction. Highest numbers of *S. hermonthica* emerged in plots with direct early sowing. Sorghum seedlings transplanted on ridges (famers' practice) were most likely already parasitized before being transplanted and therefore numbers of *Striga* were not significantly different from those in plots with direct sowing. Lowest *Striga* numbers were observed both in nurseries where mineral fertiliser or organic amendments were applied (and where sorghum yields were highest), and in plots with direct late sowing and in sowing in nursery beds in furrows (but where sorghum yields were very low). It is evident, then, that numbers of *S. hermonthica* do not bear a straightforward relationship with cereal performance. Van Ast *et al.* (2005) noted that the main difference between direct sowing and transplanting was the age at which sorghum roots were exposed to *Striga* seeds. Oswald & Ransom (2002) observed a delayed emergence of *S. hermonthica* after transplanting in a range of maize varieties. Older sorghum roots, formed before transplanting, were found to resist the parasite attack (Dawoud *et al.*, 1996). In contrast, Oswald *et al.* (2001) observed that *Striga* emergence was not reduced and that sorghum failed to produce grain yield in three out of four seasons when seedling were only 17 days old at transplanting. Apparently, age at which seedlings are transplanted is crucial. The Centre for Arid Zone Studies (CAZS, 2003) recommended that early sorghum and early pearl millet varieties should be transplanted when seedlings are 10 to 40 days old. In our experiment, transplanted sorghum seedlings were 43 and 51 days old in 2004 and 2005 respectively, even though we initially planned transplanting seedlings of 30 days. Drought spells delayed transplanting in both years.

Table 3. Sorghum yield (kg ha^{-1}), percentage of plants not bearing grains (9 m^2) and emerged *Striga hermonthica* (9 m^2), and F-values in a three-way analysis of variance in sorghum transplanting

Main factors		**Sorghum yield (kg ha^{-1})**	**Percentage of plants not bearing grains (9 m^2)**	**Emerged *Striga hermonthica* (9 m^2)**
Central Somè		152 ± 13 b	1.9 ± 0.0 a (81)	0.2 ± 0.0 b (0.9)
Assiankpa		687 ± 54 a	1.2 ± 0.1 b (33)	0.6 ± 0.1 a (7.6)
2004		400 ± 49 a	1.5 ± 0.1 a (58)	0.5 ± 0.1 a (6.2)
2005		398 ± 41 b	1.6 ± 0.1 a (59)	0.2 ± 0.0 b (1.8)
Direct early sowing		281 ± 49 b	65.3 ± 5.3a	0.8 ± 0.1 a (11.7)
Direct late sowing		63 ± 16 c	92.1 ± 2.0 a	0.2 ± 0.1 c (1.6)
In furrows on infested plot		69 ± 27 c	89.8 ± 4.3 a	0.1 ± 0.1 c (0.4)
On ridge on infested plot		237 ± 44 b	60.6 ± 5.5 a	0.5 ± 0.1 ab (7.2)
Non infested soil		537 ± 85 ab	47.6 ± 6.4 b	0.4 ± 0.1 bc (3.0)
Organic matter		632 ± 77 a	36.3 ± 5.2 b	0.1 ± 0.0 c (0.6)
Mineral fertiliser		809 ± 106 a	35.9 ± 5.9 b	0.2 ± 0.1 c (1.5)
Source of variation	**df**		**F value**	
Hamlet	1	65.92***	258.95***	84.56***
Year	1	7.60**	5.70*	50.36***
Treatment	6	27.16***	27.70***	18.15***
Hamlet x Year	1	14.08***	7.84**	17.57***
Hamlet x treatment	5	0.78 n.s	19.72***	7.96***
Year x treatment	6	1.76 n.s	0.73 n.s	1.90 n.s
Hamlet x Year x treatment	5	2.17 n.s	0.75 n.s	0.21 n.s

Values in brackets have been subjected to logarithmic transformation. Values that are followed by a different letter in a column indicate significant differences between treatment at P<0.05 with Student-Newman-Keuls test. ± indicates standard error. Significance of ANOVA: n.s. not significant; *0.01<P<0.05; ** 0.001<P<0.01; *** P<0.001

Farmers' perceptions of and constraints to nursery establishment

Farmers compared the different types of nurseries regarding their effectiveness in increasing sorghum yield and reducing *Striga* incidence. They also compared nursery practices in terms of input availability, their costs, and labour demand. Farmers preferred the nursery established on fertile, *Striga*-free plot for the following reasons: (1) chemical fertilisers are neither available nor affordable and (2) transporting organic material (dumped refuse) is labour-intensive and not everybody owns household refuse heap near their houses, (3) heaps are also valued by women, (4) using these heaps compels farmers to fence nurseries, otherwise small ruminants and poultry destroy the seeds and seedlings.

Strengths and weaknesses of sorghum transplanting were analysed with farmers (Table 4). Farmers mentioned constraints on sorghum transplanting at different stages: at nursery establishment, transplanting, and post-transplanting.

Table 4. Farmers' perceptions of sorghum transplanting.

Strengths	Weaknesses
Nurseries	***Nurseries***
1- Nurseries are manageable due to their size	1- Nurseries established late are damaged by rodents, grain eating birds, and ants
2- Germination improved compared to direct sowing	2- Intermittent drought spells result in retarded growth of seedlings on infertile and infested plots
3- Seedlings grow quickly and vigorously	3- Seedlings overgrow if the rains are late at transplanting time
4- Sorghum seedlings grow vigorously before *Striga* emergence	
Post transplanting	***At transplanting***
1- Seedlings survival after transplanting is good when this abundant rainfall just before and after seedlings transplanting	1- Farmers injure their fingers during sorghum transplanting
2- There is no need to filling gap	2- Time and energy consuming compared to direct sowing
3- Early establishment does not require labour to scare birds from the fields as compared to direct sowing	3- Farmers suffer from back-ache
4- Plants are strong and healthy	4- Limited area can be transplanted due to shortage of labour availability
5- *Striga* infestation is reduced compared to direct sowing	5- Transplanting requires a managerial skill
6- Higher yield compared to direct sowing	***Post transplanting***
7- New knowledge is acquired	High mortality rate of transplanting seedlings when a long drought spell occurs just after transplanting

In the nursery, sorghum seeds and seedlings can be destroyed by rodents, granivorous birds and ants necessitating replanting and/or the use of rodent traps, which require additional labour or costs. Unpredictable rainfall negatively affects seedling growth or delays transplanting when there are prolonged dry spells. Seedling transplantation is time-consuming and labour-demanding and it is associated with back stress and fingers' injuries (CAZS, 2003; Elzein & Kroschel, 2003; Gbèhounou *et al.*, 2004; Oswald *et al.*, 2001). Just after transplanting, a high rate of mortality can occur when there is a prolonged dry spell.

Farmers concluded that the benefits of transplanting out-weigh the constraints because it substantially increases yield and reduces *Striga* emergence. They acknowledged that transplanted plants had a head start over the germinating *Striga* compared to direct sowing. Sorghum transplanting can be a simple, effective, and adapted practices for small-scale farmers compared to other *Striga* control measures.

Effectiveness of some legumes as trap crops to control *S. hermonthica*

Results of the three-way ANOVA are presented in Table 5. Maize yield was significantly affected by hamlet and treatment, and by the hamlet x year, hamlet x treatment, and hamlet x year x treatment interaction. Production in Assiakpa (47 g / plant) was much higher than in Somè central (13 g / plant) consistent with the large differences in intrinsic soil fertility between the hamlets. Maize yield was lowest in the control, the treatment with Bambaranut, and in the treatment with the improved cowpea cultivar, and highest in the treatments with the local cowpea variety and groundnut. *Striga hermonthica* emergence was significantly affected by hamlet and by treatment. *Striga* emergence was higher in Somè central (45 shoots) than in Assiakpa (6 shoots). *Striga* emergence was lowest after the use of groundnut as trap crop. Compared to sole maize, however, several legumes performed rather inefficiently as trap crop, because emergence of *S. hermonthica* was only slightly reduced in several cases. However, the low performance of some legumes could also be partly due to the fact that prior to this trap crop experiment, cowpea was planted during the major rainy seasons of 2004 and 2005 respectively, potentially resulting in a carry-over effect. *Striga gesnerioides* occurred in plots with cowpea but not in plots with the other legumes. The number of *S. gesnerioides* was higher in Somè central (17 shoots) than in Assiankpa (2 shoots). There were no significant differences between both cowpea cultivars. The presence of *S. gesnerioides* could have negatively affected the performance of cowpea as a trap crop for *S. hermonthica*.

Table 5. Maize yield (g) per plant, emerged *Striga hermonthica* (9 m^2) and F-values in a three-way analysis of variance in maize-grain legumes intercrop.

Main factors		**Maize yield/plant (g)**	**Emerged *Striga hermonthica* (9 m^2)**
Central Somè		12.8 ± 1.4 b	1.5 ± 0.1 a (44.7)
Assiankpa		46.6 ± 3.6 a	0.5 ± 0.1 b (6.4)
2004		28.2 ± 3.3 a	0.9 ± 0.1 a (27.0)
2005		31.2 ± 3.2 a	1.0 ± 0.1 a (24.1)
Bambaranut		22.1 ± 4.7 b	1.0 ± 0.1 ab (26.9)
Sole maize		19.9 ± 3.8 b	1.2 ± 0.1 a (28.1)
Local cowpea cultivar		42.6 ± 8.4 a	1.0 ± 0.1 ab (23.1)
Tolerant cowpea cultivar (TVX 1850-01F)		22.6 ± 3.2 b	1.1 ± 0.1 a (35.0)
Groundnut		37.4 ± 6.5 a	0.8 ± 0.1 b (26.0)
Soybean		33.5 ± 4.2 ab	0.9 ± 0.1 ab (14.2)
Source of variation	**df**	**F value**	
Hamlet	1	105.29***	202.22***
Year	1	0.87 n.s	2.99 n.s
Treatment	5	5.48***	3.00*
Hamlet x Year	1	0.00 n.s	2.21 n.s
Hamlet x treatment	5	3.63**	1.50 n.s
Year x treatment	5	2.90*	0.91 n.s
Hamlet x year x treatment	5	3.58**	0.99 n.s

Numbers in brackets have been subjected to logarithmic transformation. Values that are followed by a different letter in a column indicate significant differences between treatment at P<0.05 with Student-Newman-Keuls test. ± indicates standard error. Significance of ANOVA: n.s. not significant; *0.01<P<0.05; ** 0.001<P<0.01; *** P<0.001.

Several authors have shown that grain legumes grown either in rotation or intercropped with maize reduce *S. hermonthica* incidence and improve maize yield (Carsky *et al.*, 1994, 2000; Ellis-Jones *et al.*, 2004; Gbèhounou & Adango, 2003; Kuchinda *et al.*, 2003; Kureh *et al.*, 2000; Oswald & Ransom, 2001; Oswald *et al.*, 2002). Abunyewa & Padi (2003) observed that Bambara groundnut and soybean reduced *Striga* density to less than one-third compared to two years continuous cropping.

Lessons learned from the joint experiment and development of components for FFS

To be effective, the *Striga* problem cannot be dealt with separately or with a single approach. Development of any *Striga* management strategy should involve the whole community. This necessitates participatory approaches such as participatory technology development (PTD) and Farmer Field School (FFS) to enable farmers to adopt effective, low-cost technologies to cope with *Striga* infestation and enhance their livelihoods (see Chapter 8).

A prerequisite condition for farmers' adoption of *Striga* control measures must focus primarily on the biology of the parasite. This was even more necessary considering that the majority of the farmers in Somè had insufficient knowledge of Striga species (e.g. the difference between both *Striga* species and their host specificity; the huge number of minute seeds; the attachment of *Striga* haustora to cereal roots and the below-ground damage before *Striga* emerges). Discovery learning could be achieved by artificially infesting cereals and cowpea with both *Striga* species in pots. The understanding of *Striga* biology can trigger changes in farmers' cultural practices. Farmers' attention must also be drawn to different means through which the parasite disseminates (e.g., crop seeds, farm equipments or tools, grazing animals, humans through their clothes, wind and water). This understanding of *Striga* dispersal could help preventing infestation of new plots. And finally, *Striga* shoots should be uprooted or hand pulled before flowering and burnt to prevent further build-up of the seed bank.

Differences between Somè central and Assiankpa

The largest source of variation in the ANOVAs was always the factor hamlet. This great difference is due to the different histories of both villages, with Somè central having a history of permanent cropping for 30 years without external inputs, and Assiankpa having a history of 15 years permanent cropping, and a recent history of participatory research with INRAB where fertilisers had been made available. An important question then is to what extent improved crop and *Striga* management practices, when taken up by the local populations, would help escape them from the vicious circle of poverty. The fact that often hamlet x treatments interactions were also significant likely signifies that thresholds need to be passed before treatments can be sufficiently successful. It is unlikely that without substantial external inputs (as have been provided in Assiankpa before), the people from Somè central would find a window of opportunity to escape from their biophysical (soil fertility) and social (migration of young men, entrusting of children) constraints (cf Giller *et al.,* 2006). The alternative in this low potential environment, where farmers have little or no incentive to invest in agricultural activities, is to leave agriculture and rather look for alternative sources of income such as tapping oil palm wine, temporal migration, petty trade and/or informal employment in towns (e.g., riding motorbike 'taxi', selling fuel on the black market).

Conclusion

This study indicated that farmers in Somè apply practices that could increase agricultural production and at the same time reduce the incidence of *Striga hermonthica* and *S. gesnerioides*. However, farmers' practices were not always effective. Farmers agreed that the benefits of improved sorghum transplanting practices outweigh the labour and financial constraints. But the study also indicated constraints that limit adoption of *Striga* management practices. Management of *S. gesnerioides* through varying planting dates of cowpea is problematical, because the vagaries of the climate almost force farmers to synchronise the life cycle of cowpea and its parasite. Because farmers possess incomplete knowledge of the biology of these parasitic plants, discovery learning is an essential tool that can help to trigger changes in their cropping practices. This could be achieved through a Farmers Field School. Social constraints (especially in Somè central where without substantial external inputs windows of opportunity to improve agricultural productivity may be too small) could also limit adoption of improved cropping practices. Even when soil fertility improvement can raise crop yields and reduce *Striga* abundance, successful *Striga* management can only be achieved in the long term together with other measures that improve opportunities in agriculture. It is only when farmers receive fair prices for their produce that they can be expected to invest in agricultural production. The alternative is for farmers to have to leave agricultural production and seek for alternative sources of income.

Chapter 7

Report of an attempt to measure the impact of the work in Damè-Wogon and Somè, using the livelihoods approach

Pierre V. Vissoh

Report of an attempt to measure the impact of the work in Damè-Wogon and Somè, using the livelihoods approach

Abstract

The Convergence of Sciences programme emphasises stakeholders', and especially farmers', participation as a central element in co-researching and co-learning to increase the relevance, impact, and acceptability of science to address agricultural constraints. This study documents and evaluates the impact on human and social capital assets of the work on weed management with farmers. Human and social capital are two of the five capitals in the sustainable livelihoods approach. The study reported here has a very exploratory character. Its methodology is inspired by the livelihoods approach but implementation for this study leaves a great deal to be desired. However, it seems worthwhile to report the effort, especially since the results are in the expected direction. The increase of the two capital assets measured reflect changes in speargrass and *Striga* management, a strengthened farmers' capacity to undertake their own research, and their empowerment to act as partners in interactive agricultural research. Strengths and limitations of this novel method of impact assessment are analysed and further research is recommended.

***Keywords*:** learning pathway, sustainable livelihoods, capital assets, weed management, impact assessment

Introduction

A previous study in Benin identified low adoption of weed management technologies, due to a mismatch between farmers' and scientists' theories of and management approaches to weeds (Vissoh *et al.*, 2006). In order to bridge this gap, participatory development of weed management strategies was undertaken with farmer learning groups using a demand-driven interactive approach. We hypothesised that active participation of small-scale farmers would influence the research process, and generate technologies that have more chance of being accepted and used by resource-poor farmers.

Such ambitious ideas asked for an assessment of what had actually been achieved. It is one thing to report on the results of scientific experiments that have been carried out together with farmers, as we have done in the chapters on *Imperata* and *Striga* management. It is quite another thing to assess what our work has actually achieved in terms of improvement of the livelihoods of farmers, *as seen by them*. Part of the difficulty is that the PhD process and funding constraints do not allow for a longitudinal study which could assess the longer-term impact of our work, for example on the take-up of new technologies and practices in subsequent farming seasons. The present study reports on the work of two MSc students, supervised by the author of the thesis, to measure the impact of the work in Damé-Wogon and Somè on the farmers who participated in the field experiments. The impact assessment was based on one-shot data collection relying on collective recall in the experimental groups. This methodology admittedly leaves much to be desired, as we shall have occasion to observe in somewhat greater detail later.

The attempt to measure the impact of our work was meant to be a collective exercise for all four Beninese CoS doctoral students, using a similar methodology based on the sustainable livelihoods approach. The undertaking emerged and was agreed during a supervisory visit of Dr Janice Jiggins to Benin in 2005. The idea was to write a collective chapter that would appear in each of the dissertations. This proved unfeasible. However, all of the Beninese students engaged in some efforts to measure the impact of their work on farmers, using a similar approach. Given the importance of the subject, and the need to develop a methodology for assessing the impact of our work on the livelihoods of the intended beneficiaries, we opted for publishing the preliminary results in the present short chapter.

The sustainable livelihoods approach

The concept of livelihood is increasingly used in development debates, in which people's capabilities, and social and material assets are recognised as important for making a living (Carney, 1998; Kanji *et al.*, 2005). The sustainable livelihoods approach aims to promote development that is sustainable not just ecologically, but also institutionally, socially and economically, and to produce genuinely positive livelihood outcomes (Cleary, 2003). The concept of sustainable livelihood (SL) was developed by Chambers & Conway (1992) and operationalised in the five capital assets by DFID (1999).

The SL framework identifies five core asset categories: physical, financial, social, natural and human capital assets, which are closely linked to each other (Campbell *et al.*, 2001; Castro, 2002; Cleary, 2003; Hellin *et al.*, 2003; Kanji *et al.*, 2005; Pretty, 2000). These capital assets are defined as follows: *Human capital* denotes knowledge, skills, creativity, adaptive strategies, labour availability and health. *Social capital* includes social organisation, such as government structures, networks, and communities, and institutional aspects such as decision-making, power, participatory processes, and culture; *Natural capital* refers to natural resources (land, water, air, and biodiversity). *Physical capital* consists of infrastructure (roads, buildings), machinery, transport, shelter, communication. *Financial capital* comprises cash, savings, loans/funding. These capitals are influenced by a particular vulnerability context, including trends, shocks, and seasonality over which people have limited or no control (Kanji, 2003). The five capital assets can be used for the assessment of impact of research interventions. Mancini (2006), for example, used the five capitals to assess the impact of cotton IPM field schools in India. Her work has been an important example for the present study, which aimed to (1) evaluate farmers' perceptions of changes of weed management practices after joint experimentation and social learning, and (2) analyse the strengths and limitations of the five capitals approach for assessing the impact of individual CoS projects.

The measurement of the five capital assets usually involves spider or kite diagramming which allows for easy visualisation of the self-reported assessment of the change in a given capital stock along an axis based on an estimation of the change in the asset between two time periods. The five axes become spokes of a wheel. By connecting the measured points on the spokes, for each of the two time periods, one achieves a easy to interpret visualisation of the change that has taken place. Fig. 1 gives an example of using kite diagramming from the work of Mancini (2006).

As we shall see, we could only manage to measure two of the five capital assets, viz. human and social capital, to some degree. But we did attempt to operationalise each of these assets in a number of indicators and then used the spider diagrams to visualise the results.

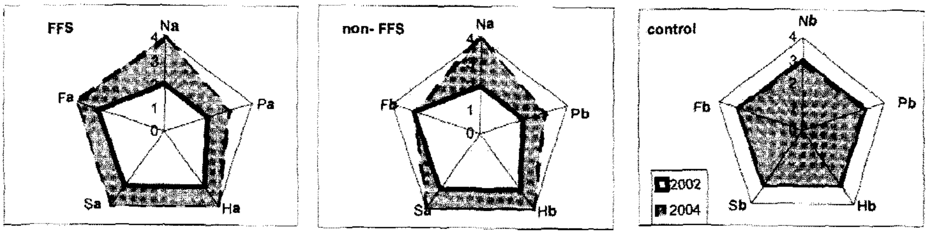

Figure 1. Changes in capital stocks recorded between the baseline year (2002) and the impact year (2004) by three groups of farmers (IPM FFS, Non-IPM FFS and Control) in Warangal. N=natural capital, P= physical capital, H = human capital, S = social capital, F = financial capital. (Copied from Mancini, 2006 with permission)

Methodology

We commence this section on methodology by describing the formation and composition of the groups that provided the data for the present chapter. We then describe in some detail how we attempted to measure the impact on the farmers, based on a comparison of two periods as recalled by the groups of farmers collectively.

Learning group at Damè-Wogon to manage speargrass

The learning group in Damè-Wogon was composed of two existing farmer groups of 10 farmers each that had operated for two consecutive years for the IPM-FFS of the *Projet Niébé* (cowpea project). The major reason for working with existing groups was that they were institutionalised in such a way that it was not possible to build another group without involving them. By using existing groups, advantage could also be taken from their previous participation in the *Projet Niébé* and other projects (e.g., SG2000 – see Hounkonnou [2001] for local dynamics in Damè-Wogon). Because cowpea is a major component of the cropping system - it contributes to food security, speargrass suppression, and soil fertility maintenance,- there was an expectation of benefit from lessons learned from the project on cowpea pest control. The selected farmers represented different local institutions in their respective villages (*e.g.,* president or secretary of cotton growers' group (*Groupement Villageois* in charge of input distribution for the cotton campaign), women's group (*Groupement des Femmes),* in charge of agricultural product processing), or local bank). Moreover, some of them were members of decision-making committees at district (Bonou) and sub-district (Damè-Wogon) level. In selecting these farmers we assumed that technologies developed with their involvement could diffuse in their villages. The total 20 of farmers who belonged to the groups comprised 15 men and 5 women. One male farmer resigned in 2004 and another male in 2005. One male farmer was not present during the group assessment on which we report here.

Learning groups at Somè to manage *Striga spp.*

In Somè, different learning groups were created in the hamlets of Assiankpa and Somè Central. These hamlets differed in their cropping history, soil fertility status, and level of *Striga* infestation (Chapter 6). In Assiankpa, the LG was built on an existing group of farmers who had formerly been involved in adaptive or demonstrative research with researchers from INRAB (*Institut National des Recherches Agricoles du Bénin*). During the CoS project the LG was expanded to include new farmers. The existing farmer group comprised 10 farmers and 5 new farmers joined the group, making a total of 15 farmers. The final impact assessment was carried out with a group of 12 farmers (5 men and 7 women), as three farmers (2 men and 1 woman) abandoned the learning group. In Somè Central, 35 volunteer farmers agreed to be members of the LG. Some farmers were accustomed to conduct on-farm adaptive trials with extension agents from the CARDER. Irregular attendance of learning sessions by some farmers due to temporary migration resulted in reduction of the number of participating farmers from 35 to 20. In the end, 11 women and 9 men were involved in the impact assessment reported in the present chapter. Despite hidden tensions (leadership conflict) between farmers of the two hamlets, farmers of both LGs agreed to meet on a regular basis to exchange experiences in the field. The learning groups in Somè included: the chief of Somè village (both hamlets) and president of the village group (GV), representatives of women groups (GF), the local extension agent and the senior researcher.

Impact assessment of social learning on farmers' livelihoods

As we said before, while the original DFID approach recommends the use of five capitals, in this study only two capitals (human and social) could be measured because the PhD process did not allow enough time for a longitudinal study to measure changes in the other three capitals (natural, physical and financial). In order to arrive at more detailed understanding of the impact the CoS project made on the two capital assets that we could assess, we decided to subdivide the two assets into a number of elements and construct spider diagrams (polygons) based on these individual elements.

The assessment was carried out under the supervision of the senior researcher by the two junior authors (S. Sambieni & E. Totin) who were MSc students at the time and engaged in the study as part of their MSc project. Lengthy discussions among the three authors resulted in a list of elements that could be used for the assessment. Similarly, the junior authors asked farmers to list their elements for the assessment. The researches' elements were crosschecked with those listed by participating farmers of the learning groups in the three localities (Damè-Wogon, Assiankpa, Somè central). In the end, a list of elements that was validated with farmers was established. The Farmer Research Groups were then asked collectively to evaluate themselves and to indicate the changes that had occurred after the experiments, based on the elements identified for operationalising each of the two capitals.

Farmers' appreciation of the tested weed management technologies was based on a single difference (before – after) design. A recall method was used to assess perceptions at the start of the co-research. The groups were asked to evaluate the change in each of the elements identified. They rated the elements for each capital, for the baseline year 2003 (starting year) and the impact year 2005, on a 0-5 scale, with the zero value indicating no stocks and the maximum value indicating full satisfaction with that stock. Data processing was carried out by the two junior authors. Following Mancini (2006), the resulting polygons were used in and with the farmer learning groups for visualisation, reflection and discussion of the ways in which the CoS project contributed to farmer empowerment.

Based on their relative importance as perceived by the farmers, they were finally asked to elicit, rank and allocate, the main factors that contributed to the changes in human and social capitals that they had observed. These factors could guide further FFS implementation. Farmers were asked to divide 20 stones into four parts, according to the weight of each factor that contributed to the enhancement of these capitals. These numbers were converted into percentages.

Results and Discussion

Elements of the two capitals

Table 1 gives the list of elements that were identified by the researcher and the farmers and subsequently validated by the farmer learning groups. The elements of human capital (in this case the individual elements of knowledge related to the biology and management of weeds) were the same in Assiankpa and Somè central. The elements should not be viewed too individualistically: the element 'speargrass suppression' refers to the whole set of practices and includes the other elements. '*Striga* biology' includes the minute seeds, while 'preventive control' includes actions that farmers could take to prevent *Striga* seed dispersal.

The list of elements should therefore be considered as an expression how in the farmer / learning group interaction with the researcher, the weed management technologies were conceptualised. The elements of social capital were the same in the three villages. Again, these elements should not be viewed too individualistically: 'decision-making' refers to the self-confidence of the whole group, while 'woman self-confidence' looks specifically at how women increased their social capital. This element was only assessed with the female members of the LG's.

Table 1. Elements identified under the two capitals (Human and Social) by farmers.

Human capital		Social capital
Damè-Wogon	Somè	Damè-Wogon and Somè
Underground depth of rhizomes	Planting dates	Trust
*Deep land preparation and hoe-weeding	Sorghum transplanting	Social organisation
***Cowpea is edible, suppresses speargrass, and improves subsequent maize yield	*Striga* species and host specificity	Farmer-researcher interaction
**Pigeonpea is edible, suppresses speargrass and improves subsequent maize yield	Soil fertility link with legumes	Farmer-to-farmer interaction
Cowpea density	*Striga* biology	Women self-confidence
Speargrass suppression	Preventive control	Decision-making
	Tolerant/resistant varieties	Start self-help saving group ('tontine')
	Food increase	

Change in human capital stock in Damè-Wogon

There was a substantial increase in the various elements of human capital (Fig. 2). On average, farmer groups ranked their initial knowledge with 2, while at the end of the CoS project their knowledge was evaluated 4. Farmers learned more about the use of pigeonpea to suppress speargrass than they did for cowpea. Most of the farmers were not aware of pigeonpea, apart from those who used it as a medicine. They were not aware that pigeonpea can be used to suppress speargrass and to improve soil fertility. However, the use of pigeonpea in the area can only come about if a market for it develops. Cowpea is already a component of the farming system, and provides food, while simultaneously suppressing speargrass and improving subsequent maize yields. Farmers have not learned much from the experiments apart from the use of novel cultivars screened by research, which the senior author introduced. While farmers realised their effectiveness in suppressing speargrass and in improving subsequent maize yields compared to their own varieties, grain production by these cultivars was too low for them to become a preferred choice. The discovery learning made farmers aware of the soil depth at which speargrass rhizomes occur. Farmers were already aware that increasing cowpea density increases the effectiveness of cowpea cultivars in suppressing speargrass and improving maize yields, but reduces grain yield. Farmers' increased human capital was expressed by one farmer who stated: "we can now buy and progressively reclaim plots severely infested by speargrass." Constraints in the implementation of this integrated speargrass management were discussed during learning sessions. These discussions centred around labour requirement, availability and cost, and around the trade off between cowpea yield, speargrass suppression and maize production. The farmers acknowledged that they were disseminating the improved practices to non-participant farmers in their villages.

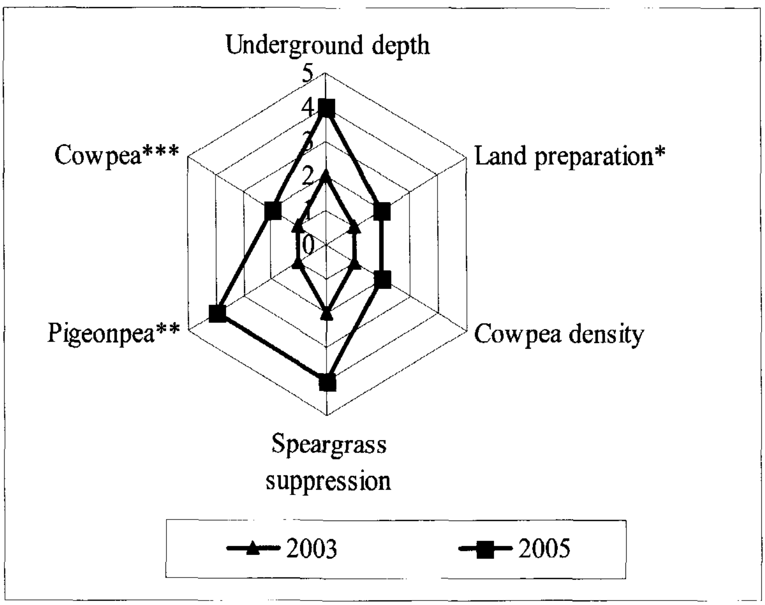

Figure 2. Change in human capital stock recorded between the baseline year (2003), based on recall, and the impact year (2005) as perceived by farmer research group at Damè-Wogon. See Table 1 for explanation of the elements.

Change in human capital stock in Somè

During the learning sessions, the biology of *Striga* was studied with farmers. The different infestation symptoms of *Striga* species were observed and discussed (wilting, growth reduction, lower yields, lower seed quality). Sorghum, maize and cowpea plants were dug up to observe the attachment of *Striga* to its hosts' roots. An artificial infestation experiment in pots was carried out with two types of soil (soil with low and high organic matter content) to enable farmers to understand that the *Striga* problem is associated with low soil fertility. Maize and cowpea were artificially infested with 3000 *S. hermonthica* seeds per pot containing either field soil or soil with organic matter addition (dumped household refuse). *Striga hermonthica* emerged in pots with field soil sown with maize but not in pots with compost. *Striga gesnerioides* emerged from pots containing field soil even though cowpea was not artificially infected with *S. gesnerioides*. This experiment showed to farmers that this soil was infested by both *Striga* species. Farmers realised that both *S. hermonthica* and *S. gesnerioides* showed host specificity. Farmers themselves identified the different means of *Striga* seed dispersal (e.g., crop seeds, farm equipments or tools, grazing animals, clothes, wind and water). We also discussed preventive measures and the constraints farmers face in applying them. For instance, farmers usually buy seeds in the market or use clothes and equipments for both infested and *Striga*-free plots. Farmers were initially of the opinion that the *Striga* problem could not be fully solved, and we spent a substantial amount of time discussing the necessity or desirability to uproot *Striga* shoots before flowering or seed set to reduce the Striga seed bank. We emphasised that no single control measure suffices to manage *Striga* and that the parasite can only be dealt by using both preventive and curative methods in an integrated crop management approach. Fig. 3A & B present changes in human capital in the two hamlets, as perceived by the groups. There were no differences between the hamlets, which is surprising, because field experiments conducted in the two hamlets showed very large differences in agricultural production.

Both villages had also experienced different interactions with science, suggesting that their knowledge of individual elements of *Striga* biology and control might well be different. Their similar assessment of human capital was probably due to the fact that farmers in both groups had joint learning sessions. Farmers also stated that they achieved better yields when they used the technologies on their own plots compared to those obtained on the experimental plots. Possibly the villages were less different than the results of chapter 5 would suggest. Farmers were to some extent aware of a relationship between *Striga* and soil fertility, and of sorghum transplanting. Their initial scores for the other elements (*Striga* host specificity, effects in the below-ground stage, and means of dissemination) were rated as 1

Farmers' perception about *Striga* changed after joint experiments and discovery learning convinced them that it is possible, on the basis of better knowledge of the parasite and the various management options, to reduce or control it. Prior to this study, farmers doubted if one can successfully combat the scourge (Vissoh *et al.*, 2006).

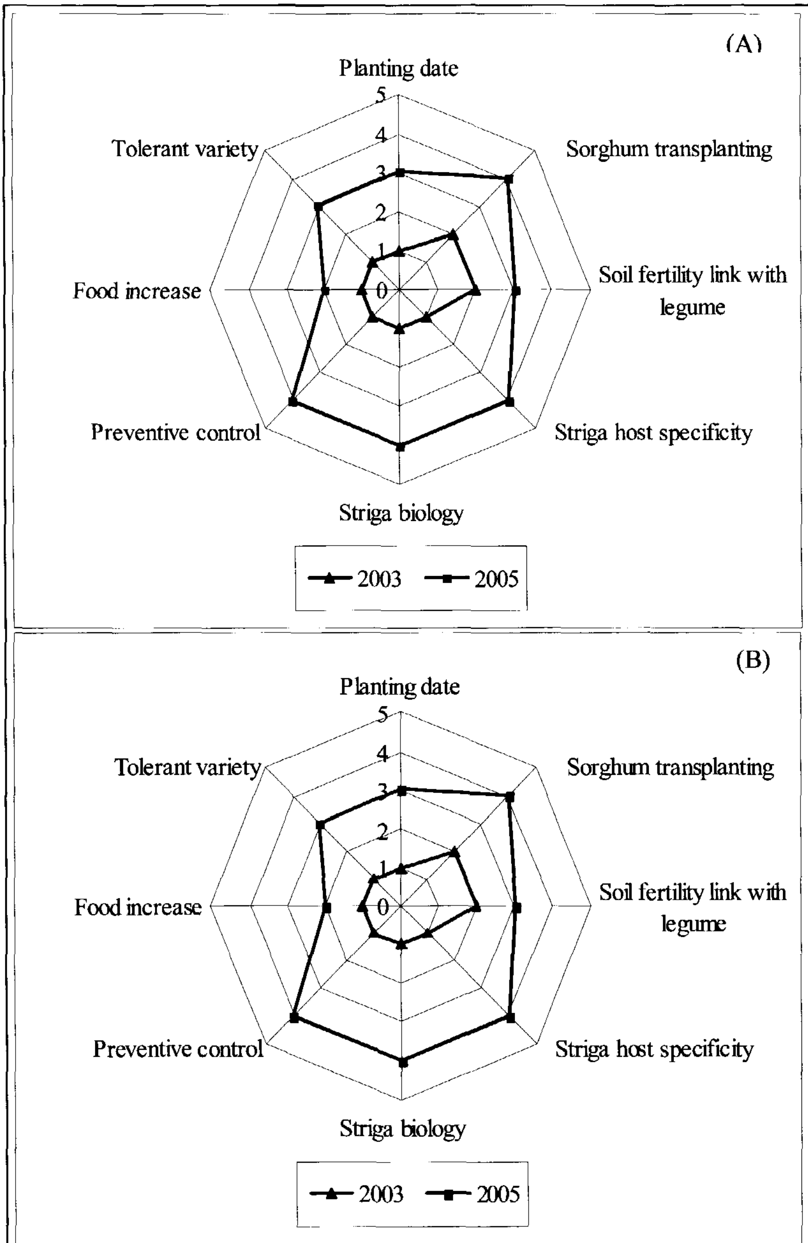

Figure. 3. Change in human capital stock recorded between the baseline year (2003) and impact year (2005) by farmers at Assiankpa (A) and Somè central (B). See table 1 for explanation of the elements.

Social capital in Damè-Wogon

According to farmers, the joint learning and interaction among themselves and with researchers and extensionists, allowed them to gain self-confidence (Fig. 4). They have learned how to participate in group discussions, exchange opinions and negotiate concerted action. Farmers' consciousness has increased in favour of social organization, exemplified by the formation of a tontine group (self-help saving group). Cohesion increased, as did common interest, and participating farmers shared strategies to overcome agricultural constraints.

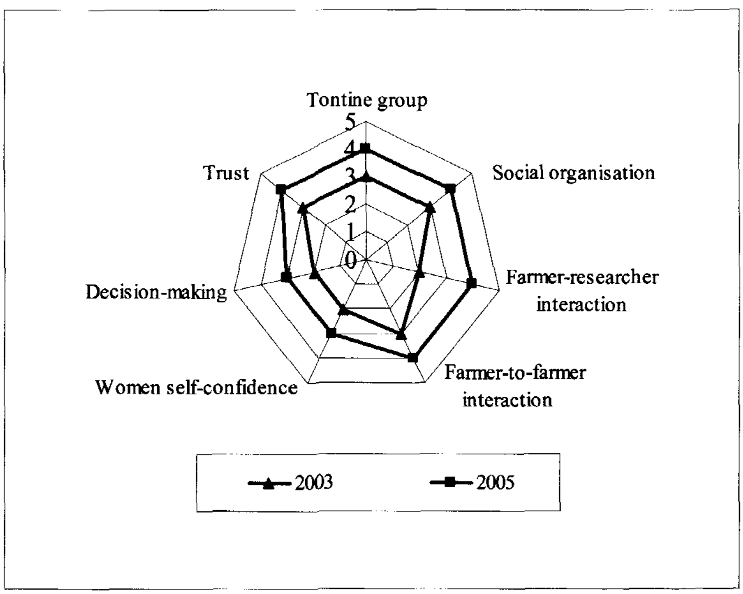

Figure. 4. Changes in social capital stock recorded between the baseline year (2003) based on recall and the impact year (2005) by farmer group at Damè-Wogon. See Table 1 for explanation of the elements.

Social capital in Somè

In Somè, initial human capital and social capital in the impact year were lower than in Damè-Wogon. This difference is likely due to the impact of previous participatory approaches implemented in Damè- Wogon (*e.g.,* IPM-FFS cowpea project, SG2000 project). Hounkonnou (2001) also reported that social organisation has triggered local dynamics in the sub-district of Damè-Wogon. In Somè (Fig. 5A & B), farmers from both learning groups met and exchanged views on common problems. That the communities in both hamlets were able to collaborate, improved their social capital. This collaboration took place despite a leadership struggle between the two hamlets. At the baseline year, there were only small differences between them. In Assiankpa 'social organisation' and 'tontine group' received a higher score than in Somè central. At the impact year, there were no differences in the individual elements of social capital between both hamlets. Farmers reported that they interacted with researchers and were offered the opportunity to voice their opinions. The establishment of a tontine group in central Somè reinforced the solidarity among group members. To prevent irregularity at the joint learning sessions, farmers decided that all members of the learning group should subscribe to the self-help saving group. Women acknowledged that not only were they able to participate in group discussions with men, which were already unusual, but also, that they were now confident to raise their point of view in the presence of men. Their changed perception is not only documented through the assessment of changes in human and social capital. The intermezzo (before Chapter 6) is another indicator that farmers have changed.

Farmers' perceptions of the factors that stimulated change in agricultural practices

The factors that led to change in both social and human capital were identified and ranked by each of the farmer groups in a final evaluation and validation of the research results (Table 2). Farmers were asked to divide 20 stones into four parts, according to the weight of each factor that contributed to the change in the two capital assets. These numbers were converted into percentages. The weights attributed to each component were consistent from one learning group to the other. The interaction farmer-researcher (social capital) scored 40%; experimentation (human capital) scored 30%, and field visits and observations 20-25%. Interactions among farmers (10-15%) received the lowest scores.

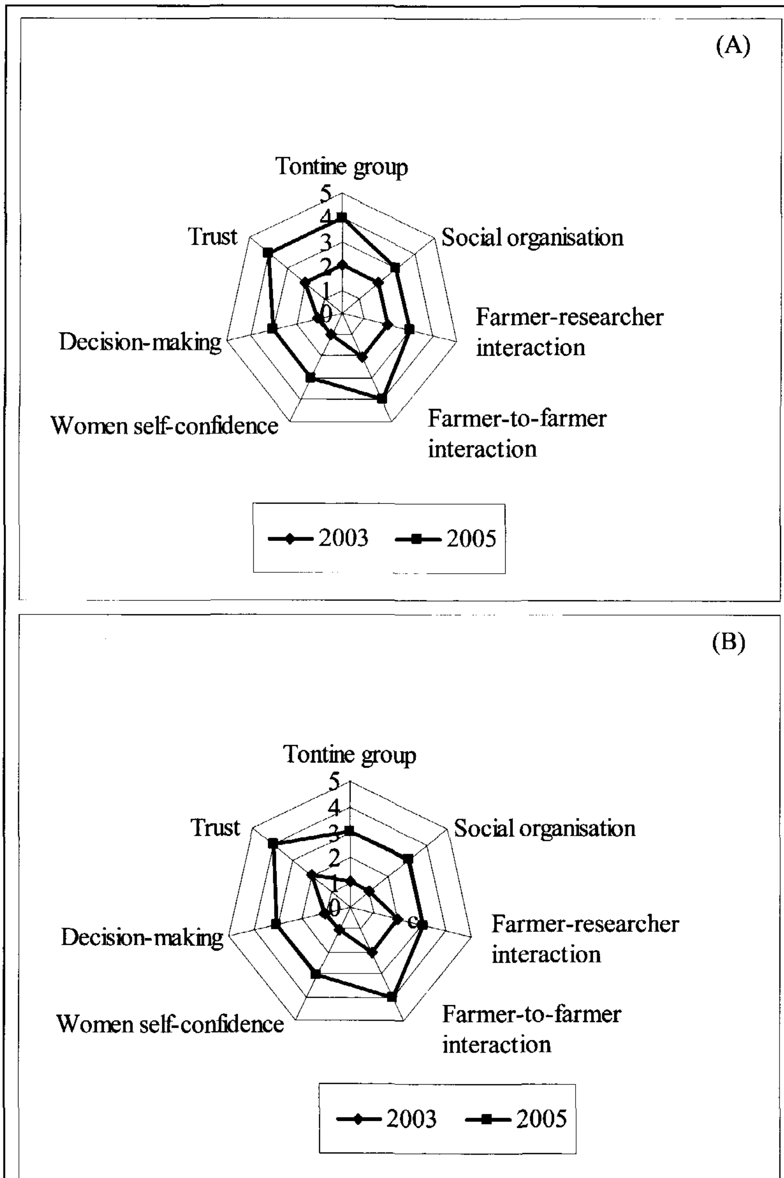

Figure 5. Changes in social capital stock recorded between the baseline year (2003) and the impact year (2005) by farmers in Assiankpa (A) and in Somè central. See table 1 for explanation of the elements.

Table 2. Ranking of factors which influenced changes in speargrass and *Striga* management during the joint learning.

Components	Ranking	Percentage allocated per factor (%)		
		LG Damè-Wogon	LG Assiankpa	LG central Somè
Farmer-researchers interactions	1	40	40	40
Experimentation	2	30	30	25
Field visits, observations and exchange of experiences	3	20	20	20
Farmer-farmer interactions	4	10	10	15

Strengths and limitations of the SL approach as applied in this study

Application of the SL approach to assess direct and indirect impacts of research projects is relatively new, as far as we know. Mancini (2006), who pioneered the use of the approach in India, mentioned a number of its limitations. In our own work we have also observed a number of them, which we briefly enumerate below.

1. The study was limited to an assessment of the project's impact on human and social capital. Changes in physical, financial and natural capitals could not be measured because it was felt that changes in these capitals would require longer time frames. It would therefore be important to revisit the areas in a couple of years, to discover to what extent the improved practices are still being implemented, and assess all five capital assets. However, from the data in Mancini (2006), who assessed all five capitals in a similar period (baseline year 2002, impact year 2004) and was able to demonstrate significant improvements in all assets, it seems that we might have been too cautious. In any case, human and social capitals are prerequisites for achieving the other capitals (DFID, 1999; ITDG, 2001). Recent development effort to promote appropriate agricultural practices has been linked to social capital through an emphasis on group formation (Tripp, 2006).
2. Because we included only two capitals, we were unable to apply the livelihood pentagon. Instead we opted for listing the individual elements of human and social capital assets, and assess these on the basis of the SL framework. It is not clear whether this overstretches the method. Too much reductionism may make the link between the *elements* of capital stocks and the general livelihood less straightforward. CoS' long-term aim is to improve

the livelihoods of the resource-poor farmers. Changes they perceive in agricultural practices are perhaps better considered as a prerequisite for improved livelihoods, than an achievement of improved livelihoods as such.

3. In our approach, human capital may have been reduced too much to intellectual capital (knowledge). It is already difficult to assess the capital stocks in the original DFID (1999) approach, due to the fact that these stocks can hardly be quantified. In our approach with its strong emphasis on knowledge capital, this problem of quantification may be even greater and the results therefore even more subjective.
4. Our assessment was a collective exercise and was not carried out by individual farmers. This precluded a subsequent statistical analysis. Group assessment may not be without problems, because it could be subject to group pressure, especially if a project, or a subsequent project that comes as a follow-up, delivers material and immaterial benefits to participants (or if participants expect such rewards). However, even individual assessments may not be without problems. There is a risk that individuals express their satisfaction by overestimating the actual impact or underestimating the baseline values. That latter problem seems possible in the study by Mancini (2006), where in both villages, control farmers, who had never been exposed to FFS, reported higher initial natural and physical capital stocks than the farmers of the FFS village who had a long association with IPM FFS. This bias (underreporting) could be an inherent risk of the recall technique.
5. The SL approach is based on a double difference design, comparing before and after, and comparing different farmer groups. Our study included only a single difference in a diachronic approach, and no villages outside the sphere of the CoS projects were included for comparison. We also did not compare with farmers in the project villages who were not members of the learning groups. Again, if learning groups provide other non-material benefits, such as prestige, to its members, this could lead to overestimating impact. Increased social capital may as well lead to exclusionary effects, where the better endowed can afford (because of time) to remain in a learning group and reap its benefits. It is therefore useful that a future study involves a disaggregated analysis for gender and wealth class. Mancini (2006) noted that individual respondents gave quite different assessments of changes in the different capitals stocks. She suggested compensating mechanisms, and implied that neither group pressure not male-biased over-reporting were important. However, the remarkable diversity among individual farmers could also point to the need for further dis-aggregation of the data. Comparing different villages with different previous histories (*cf.* interaction with earlier research in Damè-Wogon) may also be problematical. It may therefore be more important to document changes within villages than between villages.

These criticisms mainly refer to impact assessment as an extractive procedure, where researchers use these data as part of a scientific study. However, livelihoods polygons (spider diagrams) may be equally important as a dialogic tool for empowerment within farming communities (Mancini, 2006). We have also attempted to use our results for this purpose and found that the polygons create considerable interest and stimulate discussion.

Conclusion

The joint learning in the farmer research groups had a substantial impact on farmers' knowledge and skills (human capital). The improvement of local weed management strategies as perceived by the farmers suggests that the interactive approach used in the present study has been quite effective in terms of its impact on farmer learning. More than just joint learning about novel weed management practices, the CoS approach provided learning about strategies for sustainable permanent land use, a key issue in the current transition in most West African farming systems. Beyond this joint learning of weed management and cropping system strategies, farmers have acquired dynamism (been empowered) for taking initiatives with respect to social organisation. While capital stocks increased, the major concern remains to what extent farmer empowerment can ensure rural poverty alleviation. In extremely constrained areas with very limited windows of opportunity (as in Somè central), helping farmers to help themselves may just not be enough.

Chapter 8

General discussion

Pierre V. Vissoh

General discussion

Weeds are an unavoidable component of cropping systems. They have a large impact on small-scale farmers' production systems and constitute a major constraint to their livelihoods, especially during the transitional phase towards continuous cropping, when fallowing periods are too short to suppress weeds and restore soil fertility, and in permanent cropping systems. A participatory development of weed management was conducted with groups of farmers (learning groups) within the Convergence of Sciences (CoS) framework to enable them to improve integrated crop management. This process included learning from farmers about their weed practices, learning with farmers about possible improvements of these practices, and co-experimenting these practices. This concluding chapter reflects on and analyses (1) the composition of the learning groups and implications for the co-learning process, (2) the co-research process with farmers in a participatory design (3) the local crop management technologies (including the practices to manage speargrass and *Striga*) (4) some issues of the CoS approach that suggest crucial questions that a next phase should more explicitly address.

The learning group

The question how to select farmers to take part in the learning group and how to conduct joint experiments is of crucial importance. The three learning groups were built on different principles (Chapter 7). The learning group in Damè-Wogon was not formed by me, although I agreed with the decision how the group was to be composed. Scheuermeier *et al.* (2004) also recommended that farmers' selection should be left to the community. The group consisted of farmers who were members of two earlier learning groups (platforms) that were formed during the IPM-FFS project (*Projet Niébé*) that preceded CoS. The decision to continue with members of already existing learning groups avoided frustration of those who would not have been selected as members of the new learning group. Moreover, innovative farmers, who are known to have already tried out new things on their own, may be particularly useful for PTD and they might have established roles as innovators in the community. Farmers for these existing groups were selected by local authorities, based on their innovativeness, experiences, availability, and willingness to participate in joint experiments with their peers and researchers. Each farmer was a representative of a cotton growers' group (GV), a women's group (GF), or an official in a local organisation.

All group actions were preceded by discussions among members of the learning group, facilitated by the researcher. When opinions diverged initially, concerted agreement was usually reached in the end. An additional advantage of working with an existing group that had already shown its value is that these farmers can be used as facilitators in subsequent projects. They can train new farmers and so induce a multiplier effect. In contrast, in such a system, volunteer farmers have no chance to become new members of the learning group. Remaining in such groups for subsequent projects may accrue advantages for farmers of the group, while such advantages, such as access to money, credit or input, or social prestige, could also attract new farmers to join the learning group, who then would find the group effectively 'closed' (see below). The follow-up of the study on the five capital assets of the sustainable livelihoods approach (chapter 7) will have to show to what extent the pre-analytical choice to work with an existing group eased or complicated the spread of the novel weed management technologies across farmer communities.

In Somè, there was a farmers' research group committee at Assiankpa hamlet, whereas in central Somè no such group existed. Farmers in Assiankpa were more or less accustomed to research activities, but in central Somè, apart from one farmer who worked with extensionists and researchers, the members of the group I worked with were not used to research activities. The leader of Assiankpa group was also more competent in managing his group than his colleague of central Somè. It therefore took the researcher a substantial amount of time (one year) to organise farmers in a learning group in central Somè. Because the participating farmers were volunteers, their initial attendance to learning sessions was rather irregular. This irregular attendance more or less affected the activities of the group until we formed a more stable group. Irregular attendance to and defection from the learning group could have had different causes. Possibly these farmers did not believe that it was possible to improve the very low fertility of their soils, increase crop yields, and control *Striga*. Another reason could have been that under such conditions farmers cannot afford to spend (too much) time on learning activities. However, farmers' eagerness to better understand the *Striga* life cycle as a way of better fighting against it contributed to active participation by the remaining farmers during the leaning and research process. An important issue that complicated the functioning of both groups in Somè was an issue of leadership. Farmers in Assiankpa hamlet thought that they were competing with their colleagues of central Somè. They usually compared themselves and the results they achieved to those of central Somè. Because both hamlets were different in both biophysical (soil fertility) and social (previous interaction with science and its attendant benefits in terms of inputs) characteristics, this leadership issue could be an expression of more general competition for resources that science and other projects almost inevitably bring. Even though farmers from both hamlets interacted a lot and the results of the study on the five capitals showed surprisingly similar outcomes in their assessment of human and social capital, such issues of leadership and competition seem to deserve more attention.

A drawback of using existing groups is that farmers want to obtain financial compensation for the time spent during learning sessions. They usually compare their benefits, including material benefits, to those offered by previous research and development projects. In Damè-Wogon, the pressure of the group and the intervention by local authorities prevented that issue, which was raised by several young farmers, from influencing the functioning of the group. While this is another advantage of relying on the community for selecting group members, it also raises questions on how interactions within a group (social learning could also generate conformism in groups through 'group pressure') could affect the co-learning and co-research process. Similarly, in Assiankpa, farmers compared the benefits received from the CoS project to those offered by researchers of earlier projects. More specifically, they compared the different experiments on soil fertility in terms of benefit. Earlier projects involved the use of inorganic fertilisers, while in the CoS project fertiliser use was hardly part of weed management and cropping systems management. For farmers, who may keep the harvested products as compensation for involvement in the project, benefits of experiments with fertiliser may be quite attractive, sometimes more so than a CoS-like project. It is therefore important that at the beginning of future projects, farmers are made aware of the conditions under which the research will be implemented. It is then important that issues of human and social capital (including farmer empowerment) are brought to the front in participatory research.

We should continue to reflect on the possibility that such issues (and the comparative benefits of those compared to projects with more direct intervention) are insufficiently grasped or accepted by small-scale farmers. For a next phase of a CoS-like programme, it is essential to explain to local authorities and participating farmers their roles and responsibilities as well as accompanying measures that such projects may or may not provide. It is certainly risky (and sometimes even useless from a long-term perspective) to pay farmers for their involvement, because the payment creates very artificial conditions that make it highly unlikely that anything will remain after the project has ended and the project workers have departed. As the objective of PTD is to find out new things that work under farmers' natural conditions (instead of under artificial conditions), no money should in principle be paid to farmers.

Joint experimentation

Practical experiments were carried out together with groups of farmers to strengthen farmers' knowledge so as to enable them to discover new things and new ways that work. The experiments carried out were a combination of elements of farmers' technologies or a combination of farmers' and scientists' management strategies to address some of the constraints to agricultural production caused by speargrass and *Striga*. The experimented technologies were compatible with and embedded in the local knowledge system. In a next phase, the impact of this joint experimentation on farmers' production and hence on their livelihoods (the five capitals of Chapter 7) should be assessed. Both individual and group assessments should be conducted to determine long-term change on individual farms and to evaluate farmer-to-farmer diffusion of these technologies.

Interactive research implies the integration of modern science and local knowledge. One of the key differences between indigenous knowledge and western science is that the former is embedded in its context, while the later thrives on abstract formulation in a context-independent way. Such research is therefore often separated from the daily lives of the investigated (Agrawal, 1995; Biggs, 2005; Homann & Rischkovsky, 2001; Pretty, 1994). One major challenge for CoS is to develop an effective methodology to incorporate local knowledge systems into scientific processes and to integrate (interpretive) signs with (explanatory) mechanisms (Pawson & Tilley, 1997). Such a methodology should not be substitutive, *i.e.*, reduce local knowledge to (more primitive) forms of scientific knowledge, or show that local knowledge was after all correct (and science wrong), but explore possibilities for synergism. Sumberg & Okali (1997) were sceptical of this synergy hypothesis, arguing that farmers' experiments are complementary rather than synergistic to formal agricultural research efforts, and claiming that farmers' experiments are more closely akin to extension activities than to research accomplishments. However, while my study of weed management would support their thesis, experiences in the framework of the CoS programme (*e.g.*, the role of cassava in soil fertility) would also allow room for further work on exploring and exploiting synergy between different forms of knowledge.

Local crop management and strategies to combat speargrass

As shown in Chapter 5, the emergence of speargrass as a major weed is both a consequence of agricultural intensification (leading to shorter fallowing periods) and a cause for further intensification towards permanent cropping systems. As a consequence of this evolution in cropping systems, farmers' traditional knowledge is not adequate any longer and there is a need for novel technologies. Permanent cultivation of the land to prevent re-infestation by speargrass compels farmers to adopt soil fertility management practices that maintain soil productivity as far as possible; otherwise harvests will decline over time. One obvious solution for farmers is to practise cereal rotations with legumes. Such rotations are especially successful with more intensive speargrass control methods through improved practices (Chapter 5). While such systems show potential triple benefits (grain production by the legume, soil fertility maintenance through N_2-fixation, speargrass suppression), labour shortage and the high costs for hiring labour limit the scale at which this novel strategy can be applied. The best solution for farmers seems to be to gradually reclaim infested plots and thereby raise their access to credit. Under such conditions, the attractiveness of fertilisers could also gradually increase – provided there is a market outlet for their additional produce. Up to now the niche for the legume in this rotational system is filled by the local cowpea cultivar *wan*, which combines a fairly high grain yield with a fairly high vegetative biomass (which relates to speargrass suppression and soil fertility enhancement). Considering farmers' preferences, there could be space for further development of cowpea cultivars through participatory breeding, especially if the vagaries of the climate make the use of shorter-duration cultivars imperative. Another issue for further research would be whether other legumes, such as pigeonpea, could create and subsequently fill part of the niche for legumes. At present pigeon pea cannot fill that niche for both ecological (long maturation time) and cultural (non-use as food item) reasons, suggesting that future research should look towards both ecological and socio-cultural dimensions.

Local crop management and strategies to combat *Striga spp.*

Chapter 6 showed that intensification of cereal production without external inputs is the main cause of *Striga* problem. Therefore, farmers in central Somè experienced problems of low crop yields and large *Striga*-related yield losses more strongly than those in Assiankpa. Moreover, lack of knowledge of *Striga* biology prevented farmers from adopting strategies to keep *Striga* infestation at manageable and acceptable levels. An important issue for this CoS-project was to determine the extent to which the *Striga* problem could be solved in the near future. A comparison with the *Striga* problem in the USA unavoidably indicates a pessimistic answer to that question. In the USA, the occurrence of *Striga* resulted in the initiation of a drastic quarantine and eradication programme, comprising the prevention of the spread of *Striga* seeds to non-infested areas and depletion of the *Striga* seed population in the soil of the already infested areas (Van Ast, 2006). However, this massive eradication programme failed even in the USA, and after more than 50 years, the parasite, which was once inadvertently introduced, has not completely disappeared. It is clear that the option of a massive state-led *Striga* eradication programme will fail in Benin (and other African countries), so this option is illusory. One should admit that the *Striga* problem in Africa will not be solved in the near future.

Research should therefore be directed towards maintenance of reasonable crop yields (also through maintenance of soil fertility), while preventing the further build up of a *Striga* seed bank and spread of *Striga* to un-infested areas. In soils with high organic matter content (household refuse), *Striga* seeds do not germinate at all. But organic matter availability is limited because of lack of plant material in a very degraded environment as in Somè, and the near absence of livestock. Furthermore, composting has been rejected by farmers because of the intensive labour it requires. Improved methods for sorghum transplanting provided effective control methods to reduce *S. hermonthica* incidence on sorghum, but the intensive labour required will likely be a major constraint to its adoption on a larger scale. Farmers could vary planting dates of crops to avoid synchronisation of both crop and *Striga* seed germination, but experiments showed that planting early and late were both risky due to the vagaries of the climate. Under such conditions farmers are almost forced to synchronise the life cycle of crops and the parasite. Raising the soil organic matter content (with an effect on the use efficiency of rainfall water by plants) increases the opportunities for farmers to uncouple both life cycles. Experiments are needed to test through what means soil organic matter levels can be increased, with what effects on crop yields and *Striga* reduction. Possibly grain legumes could fill in this niche, the more so because such legumes can also act as trap crops that cause suicidal germination of *S. hermonthica* seeds. The use of grain legume (groundnut, cowpea, bambara groundnut) in crop rotation or intercropping is not new is the study area, but soybean is a newly introduced crop for which a niche exists. The niche for soybean (and also for groundnut) could be enlarged, because both crops can be attractive as an alternative to cotton. Cotton cultivation is currently being abandoned due to the crisis in (and even collapse of) the cotton sector. However, while the potential niche for such legumes is clear, its actual niche at present is more limited. Grain legumes did not perform well. The yield increase of subsequently grown maize was also small in a legume rotation. Poor performance was most likely due to low soil fertility, which in combination with erratic rainfall conditions, led to low growth efficiencies. Again, it is clear that soil fertility improvement is of prime importance, so that grain legumes can perform better as N_2-fixers and as trap crops. Their contribution to the growth of subsequent cereals, through improvement of soil fertility, will also depend on their harvest index. Legumes that produce a lot of grain and little vegetative biomass, like many modern varieties of cowpea and soybean, could even result in net N removal (Vanlauwe & Giller, 2006). However, the need to bridge the hungry gap (and hence the need for large legume grain biomass) may be the main determinant for farmer preference for legume cultivars (Chapter 5).

The rather limited beneficial effects of improved practices on yields of food crops (cereals, legumes) would certainly limit farmers' willingness to take up improved management practices, especially when they are labour-intensive. However, farmers considered improved transplanting worth the additional effort. Additional measures that affect the *Striga* seed bank (removal of *Striga* plants just before flowering through hand pulling) will even meet with less enthusiasm, because in the initial phases of highly infested fields, a reduction of *Striga* numbers will have no effect on crop yields (Van Ast, 2006). Research through participatory plant breeding could provide resistant and/or tolerant cultivars. But under conditions of low soil fertility, the use of resistant and tolerant cultivars may still result in very low yields. Often the low market prices for the grain of such resistant cultivars make them even less attractive to farmers.

In the end, one may well wonder whether this vicious circle of *Striga* damage, low crop yields, low soil fertility, and low human and social capital can be broken without outside intervention, *i.e.*, without creating artificial conditions that make a substantial yield increase possible. For instance, loans could be provided in kind to farmers in order to enable them to apply a complete package of integrated crop management practices (e.g., resistant varieties of cereals and cowpea, organic fertilisers through crop rotation and intercropping with grain legume trap crops, and minimum inorganic fertilisers' application, timely weeding). But bringing back the soil in a good condition is not enough; farmers must also be given fair market prices for agricultural products to enable them to reimburse these loans. These suggestions can only be achieved with the involvement of decision-makers, researchers, extensionists and NGOs. It is therefore unfortunate that the CoS-project left the area without a clear follow up.

Weaknesses of the CoS approach

During the execution of the project, we experienced a number of drawbacks that may be related to the specific character of the CoS approach. Using a bottom-up methodology embedded in a trans-disciplinary approach is time-demanding for researchers. The present study required a whole year to learn from farmers their weed management practices as part of their cropping decisions and to discuss with them the strengths and weaknesses of their practices, before engaging in joint experimentation. The approach was also (or even more so) time demanding for farmers. Some farmers left the learning groups due to time constraints. Time-demanding projects may in the end select for farmers with above-average wealth who can afford to allocate time to such group activities, or select for farmers with larger than average income through sources outside agriculture. The present project has not looked at the latter question in sufficient detail.

Secondly, implementing the CoS approach entailed a trade off between doing science and doing experiments with farmers, as farm experiments could not always meet rigorous research standards (Tripp, 1991). For example, doing experiments with poor farmers who possess only a small area of land (as in Somè central – see Chapter 6) makes replication very hard or impossible. Treating individual farmers as replicates in a statistical analysis does less than justice to the skills of individual farmers and treats the consequences of differential farmer practices as random noise. An alternative to avoid compromising scientific rigour could be that the formal experiment be conducted on-station taking into account appropriate experimental designs and all relevant scientific parameters in combination with experiments under farmers' conditions that do not meet these standards of rigour (mother- baby approach). However, exclusive attention for the mother – baby approach could be interpreted in the framework of the scepticism expressed by Sumberg & Okali (1997) that farmer knowledge and practices have little to contribute to science.

The CoS-project provided indications that experimenting with farmers does not inevitably lead to loss of scientific rigour, and that a diversity of solutions how to do scientific experiments with farmers should be explored. Such new forms of co-learning and co-researching are still local and context-dependent. Scaling out/up of these practices could be achieved through Farmer Field Schools. In the coming years, a survey should be carried out to identify to which extent participating farmers have continued to use these technologies on their farms as well as the extent to which these technologies were spread to different villages.

For a follow-up of the CoS approach, the following issues need to be dealt with in order to strengthen the achieved results: (1) the institutional aspects of the participatory approach in order to facilitate scaling up/out of the research process; (2) the socio-economic evaluation of developed technologies, and (3) the provision of accompanying measures to strengthen achieved results. The improved weed management strategies are still restricted to Somè and Damè-Wogon and most likely are not sufficiently internalised in research, policy and government institutes in Cotonou (or Wageningen, for that matter).

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Summary

Population growth in Benin and other countries of sub-Saharan Africa resulted in higher pressure on arable land, forcing small-scale farmers to bring into cultivation marginal lands and to shorten fallow periods. Because fallow controls weeds and improves soil fertility, the shift towards more permanent land use has caused the emergence of new herbaceous weeds. Subsequently, novel weed problems become a driving force for further agricultural intensification. In this respect, resource-poor farmers face a number of constraints, such as lack of access to fertilisers and herbicides, high costs of such inputs if available, and increasing demand for and costs of labour. Climate change (perceived as lower or more irregular rainfall, but more manifest through the decrease in rainfall use efficiency by crops) results in poorer plant growth, higher weed interference, and even lower yields. Low market prices and low investments in agricultural production keep farmers in a permanent vicious cycle of poverty.

Agricultural research has had limited impact on farmers' livelihoods due to an unsuitable linear research approach to the generation and dissemination of technologies for small-scale farmers operating in a complex and risk-prone environment. To increase impact on small-scale farmers' livelihoods, this study on weed management, carried out within the Convergence of Sciences (CoS) programme, envisaged that agricultural research should be trans-disciplinary in order to enhance the effectiveness, appropriateness, and acceptability of the technologies developed. This trans-disciplinary approach tried to integrate both biological and social sciences, and modern sciences and local/indigenous knowledge. Emphasis was placed on small-scale farmers' involvement to enable them to influence the research process. This was achieved through interactive learning of integrated crop and weed management. In order to be self-reliant in managing their cropping systems, the study built upon local weed and soil management practices so as to foster changes in farmers' cropping practices, and documented and evaluated the relevance of collaborative research as a better approach to technology development focusing on human and social capital, essential for achieving sustainable livelihoods.

The research pathway comprised (1) technographic studies conducted by a multidisciplinary team to select broad themes, stakeholders, study areas and communities that might be involved in action research; (2) diagnostic studies carried out in the different agro-ecological zones of Benin to validate the pre-analytical choice to work on weeds, previously made by the researcher, and to anchor the research in farmers' needs; (3) joint experimentation through discovery learning with learning groups of farmers in two selected villages. The main objective of the co-researching process was to strengthen small-scale farmers' capacity through participatory development of weed management technologies that are effective, acceptable and require low investment. The study was carried out in Damè-Wogon (district of Bonou) and Somè (district

of Za-Kpota), two villages located in the southern agro-ecological zone (Chapter 2), where speargrass and *Striga* are major weeds, causing substantial crop losses and keeping people in a seemingly vicious circle of poverty.

The conceptual framework analysed previous research paradigms (Chapter 2) under which weed management technologies were developed and disseminated. These supply-driven, top-down paradigms were considered to be inadequate to be used under farmers' conditions. Developed weed management technologies did not take into account social and economic dimensions of weed problems, such as labour (availability, costs, the humiliating nature of weeding) and market prices of agricultural produce. Despite the move towards participatory approaches (*e.g.*, Farming Systems Research, Participatory Technology Development), farmers have not yet appropriated the research process. Emphasis in the CoS programme was placed on democratisation of science and empowerment to enhance farmers' self-reliance.

The diagnostic study (Chapter 3) established that weeds constitute an important constraint on crop production, especially in areas where there is a high pressure on available land. Among the most troublesome weeds identified were *Imperata cylindrica* (speargrass) and the parasitic weeds *Striga hermonthica* and *S. gesnerioides* (witchweed). In the transitional and northern agro-ecological zones weed problems are not as severe as in the southern zone because farmers still practise shifting cultivation with fallow periods ranging from 4 to 10 years. The dominant weed control strategy remains hand/hoe-weeding, which compels farmers to devote more than 50% of their time to weeding. Lack of labour results in very high costs for hired labour, and this, in turn, forces farmers to strategically perform weedings, reducing the numbers to levels that are inadequate to control weeds. The consequence is that weeds cause substantial crop losses. The use of herbicides as an alternative to hoe-weeding is constrained by the non-availability of herbicides and their very high costs, including sprayer costs. Recommended weed management technologies have received little acceptance from farmers (e.g. use of *Mucuna* spp., herbicides, tolerant or resistant varieties). Farmers' strategies to manage speargrass consisted of digging out speargrass rhizomes. This method is labour-intensive (*e.g.*, 175 man-days per hectare). Farmers shifted to ridging, a practice that recycles nutrients and reduces weed invasion. In Damè-Wogon, farmers used integrated methods consisting of ridging, and planting of (leafy) cowpea varieties to suppress speargrass and to increase subsequent maize yield. Farmers in Somè, as part of their cropping systems management, developed a range of measures including varying planting dates and rotation and intercropping with legumes. These practices are intended to raise production, while at the same time reducing *Striga* interference. Transplanting of sorghum was used to better manage the cropping calendar, not as a *Striga* control method.

Chapter 4 describes how different actors (farmers, officials and researchers) socially constructed weeds. Archival research, literature review, informal and semi-structured

questionnaires, and participant observation were used to better understand how the different actors perceived and reacted to weed problems. Data analysis focused on population pressure on land, technology development by farmers and researchers, and the level of adoption of recommended technologies. Farmers' names for weeds were analysed. Positive valuations of weeds were assessed. The social dimensions of weeds were analysed as a major element of the vicious circle of rural poverty. The results indicated that the new generation is witnessing an acute land shortage and that both speargrass and *Striga* species have become constraints to crop production during the past 20 years. Farmers' local names to weeds reflect the extent to which they are difficult to manage and the losses they inflict on crops. Weeds are also used as roofing materials and source of income (*e.g.*, speargrass), as vegetables or animal feeds, and as herbal medicines. Several weeds are also regarded as soil fertility indicator. The introduction of cash crops (*e.g.*, cotton and oil palm) resulted in the disintegration of traditional social organisation and the rise in labour costs. Weed problems compel resource-poor farmers to entrust their children to wealthier people. This phenomenon (termed *vidomègon*) reduces the labour force available for weeding. Women suffer more than men from weed problems, due to the prevailing land tenure system.

The colonial administration, the second actor we considered, looked at weeds as a constraint in tree plantations, but showed very little interest in weeds in food crop production systems.

Recently, agricultural research, the third actor, recognised weeds as major constraint to crop production, but the developed weed management practices did not fit in the cropping systems. This mismatch of different constructions (conceptualisations) of weeds by farmers and researchers led us to engage in joint experimentation and social learning with farmers to develop speargrass and *Striga* spp. management strategies that farmers desire and can use.

Farmers' local technologies to manage speargrass were assessed in joint experimentation and discovery learning in Damè-Wogon (Chapter 5). We proposed improved speargrass management practices consisting of deep ridging and deep hoe-weeding, sowing of cowpea or pigeonpea at higher densities, treatment of cowpea plants with botanical pesticides, and deep ridging to incorporate cowpea residue into the soil for subsequent maize crop. These new practices are more labour-demanding than farmers' original practices. Five different cowpea cultivars and two pigeonpea cultivars were tested for speargrass suppression, grain yield, and enhancement of subsequent maize yield. Speargrass shoots and rhizome biomass in the control plot increased with 31 and 17 % per month respectively, while a significant decrease was observed in all other treatments. Farmers' traditional practice was significantly less effective than the improved practices. Late-maturing, creeping cowpea varieties suppressed speargrass better than early-maturing, erect varieties. The relationship between cowpea leaf mass and rhizome suppression was highly significant. However, cowpea leaf mass was significantly negatively correlated with

cowpea grain yield. A significantly positive correlation was observed between cowpea leaf mass and maize yield, and maize yield was negatively correlated with cowpea yield. Farmers have to trade off cowpea grain yield (to bridge the hungry gap) against speargrass suppression and soil fertility enhancement. Farmers preferred the early-maturing, erect cowpea cultivar *wan* over the other cultivars. Apparently socio-economic factors (food, market prices for different cowpea cultivars) override technical factors related to soil fertility and speargrass suppression. Farmers also preferred late-maturing pigeonpea over an early-maturing cultivar. The marginal rate of return of cowpea variety *wan* was three times higher than for pigeonpea, which is consistent with farmers' preference. While pigeonpea had an acceptable marginal rate of return, pigeonpea does not fill a niche in the cropping system, because the cultivation of the late-maturing variety forces farmers to forego one harvest. At present, there is also hardly any market for pigeonpea. While the improved speargrass management practice was much more labour-intensive than farmers' original practice, farmers took up the new one, claiming that the improved practice allowed them to gradually reclaim land that they had abandoned due to speargrass infestation.

A similar research approach was used to evaluate integrated crop management strategies in permanent land use systems in two hamlets of Somè (Chapter 6). Both hamlets differed in natural capital (degree of soil fertility decline) and social and human capital (previous experience with research, including fertiliser trials). The extremely low yields obtained in central Somè, compared to Assiankpa, strongly suggested the need for using external support of integrated crop management because, under these conditions, local dynamics would be insufficient to increase the windows of opportunity. Before testing various technologies that could increase crop yields (cereals and cowpea) and decrease *Striga* incidence, we engaged in joint learning, which enabled farmers to recognise the host specificity of both *Striga* species and to understand the life cycle of the parasite. Farmers also became aware of the mechanisms through which *Striga* disseminates. An experiment with different planting dates of cowpea as a means of escaping *S. gesnerioides* shows the extent of the constraints farmers face. Both early sowing and late-sowing of cowpea imply a substantial risk of yield failure, due to the vagaries of rainfall and the low rainfall use efficiency of the crop. As a consequence, farmers are almost forced to synchronise the life cycles of cowpea and its parasite. An experiment to test the effectiveness of various ways of sorghum transplanting on cereal yield and reducing *S. hermonthica* interference showed that transplanting sorghum from nursery beds enriched with mineral fertilisers and organic matter was most effective. Delayed direct sowing of sorghum also resulted in low *Striga* interference, but sorghum yields were extremely low due to insufficient rainfall combined with low rainfall use efficiency by sorghum. However, the most successful strategy, increasing soil fertility, seemed beyond the reach of farmers, because inorganic fertilisers are too costly (and often not even available) and transporting organic matter is labour intensive. Farmers therefore preferred

nurseries established on fertile *Striga*-free plots. While this practice is also labour intensive, it is a simple low-cost technology, effective and adapted to small-scale farmers' conditions. An experiment with various legumes (which enhance soil fertility and also can act as trap crops that cause suicidal germination of *S. hermonthica*) indicated that legume performance was strongly limited by the very low levels of soil fertility. Again, this provided strong evidence that the *Striga* problem can only be successfully addressed if soil fertility levels are substantially increased. We also concluded that an effective control of *Striga* species requires a collective and integrated approach which involves the whole community. This is best achieved through participatory approaches such as Participatory Technology Development and Farmer Field Schools.

This study on weed management used a bottom-up approach that encouraged farmers to articulate their demand, voice their expectations and influence the research process, based on their practices. In chapter 7 we describe a self-assessment of the farmers, using the sustainable livelihoods approach. Of the five capitals assets, only human and social capital were assessed in a diachronic approach. Farmers in Damè-Wogon and in both hamlets of Somè mentioned an increase in human (skills and knowledge) and social (self-confidence and organisation) capitals. We also comment upon the strengths and weaknesses of the sustainable livelihoods approach to determine impact of research projects, such as the one reported in this dissertation, through farmers' self-assessment.

Résumé

La croissance démographique au Bénin et dans les autres pays d'Afrique sub-Saharienne a entraîné une forte pression sur les terres arables, forçant les petits producteurs à mettre en valeur les terres marginales et à raccourcir les périodes de jachère. L'évolution vers une utilisation permanente du sol a eu pour conséquence, l'émergence de nouvelles espèces herbacées. Par conséquent, de nouveaux problèmes des mauvaises herbes sont apparus dans un contexte d'intensification agricole. A cet égard, les producteurs aux ressources limitées font face à plusieurs contraintes tels que le manque d'accès aux intrants (engrais et herbicides), les coûts exorbitants de ces intrants lorsqu'ils sont disponibles et une demande croissante de la main d'œuvre dont les coûts sont élevés. Le changement climatique (perçu comme une pluviométrie faible ou plus irrégulière, mais plus manifeste à travers la baisse de l'efficacité de l'utilisation de l'eau des précipitations par les cultures) entraîne une plus faible croissance végétale, une incidence plus accrue des mauvaises herbes, et des rendements plus faibles. Des prix de ventes peu rémunérateurs et de faibles investissements dans la production agricole maintiennent les producteurs dans un cercle vicieux de pauvreté.

La recherche agricole a eu peu d'impact sur le mieux-être des producteurs à cause d'une approche de recherche linéaire non adaptée de développement et de dissémination de technologies aux petits producteurs opérant dans un environnement complexe, incertain. Pour augmenter l'impact de la recherche sur le mieux-être des petits producteurs, la présente étude sur la gestion des mauvaises herbes conduite dans le cadre du projet Convergence des Sciences (CoS) a envisagé que la recherche agricole devrait être trans-disciplinaire pour accroître l'efficacité, l'adaptabilité et l'acceptabilité des technologies développées. Cette approche trans-disciplinaire a essayé d'intégrer au mieux les sciences biologiques et sociales d'une part, les sciences modernes et les connaissances locales/endogènes d'autre part. Un accent particulier a été mis sur la participation des petits producteurs afin de leur permettre d'influencer le processus de recherche. Ceci a été réalisé à travers un apprentissage interactif de la gestion intégrée des cultures et des mauvaises herbes. Cette étude a tenté d'améliorer, d'évaluer et de documenter avec les petits producteurs, les pratiques locales de gestion des mauvaises herbes et des cultures. Ceci a contribué à renforcer leur capacité de prise de décision dans la gestion de leurs systèmes de culture. Un accent particulier a été mis les éléments du capital humain et du capital social indispensables pour l'amélioration d'un mieux-être durable. Le processus de recherche comprend (1) les études technographiques conduites par une équipe multidisciplinaire pour sélectionner des thèmes généraux, les acteurs, les milieux d'étude et les communautés qui devraient être impliquées dans la recherche action ; (2) les études diagnostiques effectuées dans

les différentes zones agro écologiques du Bénin pour valider le choix préalablement fait par le chercheur de mener des recherches sur les mauvaises herbes et de prendre en compte les besoins des producteurs ; (3) une expérimentation collaborative basée sur l'apprentissage conjoint par découverte avec des groupes de producteurs dans deux villages sélectionnés. L'objectif principal du processus de recherche conjointe était de renforcer la capacité de recherche des petits producteurs à travers le développement participatif de technologies efficaces de gestion des mauvaises herbes, acceptables et à failes coûts d'investissement. Cette étude a été conduite à Damè-Wogon (district de Bonou) et à Somè (district de Za-Kpota), deux villages situés dans la zone agro écologique du sud (Chapitre 2), où le chiendent (*Imperata cylindrica*) et deux espèces de *Striga* (*Striga hermonthica* et *S. gesnerioides*) sont des mauvaises herbes parasites redoutables qui occasionnent des pertes substantielles de récoltes, maintenant les populations dans un cercle vicieux de pauvreté.

Le cadre conceptuel a analysé les modèles antérieurs de recherche (Chapitre 2) utilisés pour le développement et la dissémination des technologies de gestion de mauvaises herbes. Ces modèles dirigistes axés sur l'offre étaient considérés inadéquats pour générer des technologies devant être utilisées dans les conditions paysannes. Les technologies de gestion des mauvaises herbes développées n'avaient pas pris en compte les dimensions socio-économiques et culturelles des mauvaises herbes tels que la main d'oeuvre (disponibilité, coûts, le caractère avilissant du sarclage manuel) et le prix de vente des produits agricoles. Malgré le changement en faveur des approches participatives (par exemple la recherche en milieu paysan, développement participatif de technologie), les producteurs ne se sont pas encore appropriés le processus de recherche. C'est pourquoi, l'accent est mis dans le projet Convergence des Sciences sur la démocratisation de la science et l'autonomisation des producteurs.

L'étude diagnostique (chapitre 3) a révélé que les mauvaises herbes constituent une contrainte majeure à la production agricole, spécialement dans les milieux à forte pression démographique sur les terres disponibles. Au nombre des mauvaises herbes les plus redoutables identifiées étaient *Imperata cylindrica* (chiendent) et les plantes parasites *Striga hermonthica* et *S. gesnerioides* (herbe sorcière). Au Bénin, dans les Zones agro écologiques de transition et du nord, les problèmes de mauvaises herbes ne se posent pas avec autant d'acuité comme dans la Zone sud parce que les producteurs continuent de pratiquer la culture itinérante sur brûlis avec des périodes de jachère variant de 4 à 10 ans. Le sarclage manuel reste la stratégie dominante de contrôle des mauvaises herbes, ce qui force les producteurs à consacrer plus de 50% de leur temps à la gestion des mauvaises herbes. Le manque de main d'oeuvre entraîne des coûts élevés de la main d'oeuvre salariée, et ceci en retour force les producteurs à prendre des décisions stratégiques d'entretien des cultures, réduisant ainsi le nombre de sarclages manuels à des niveaux inadéquats de contrôle des mauvaises herbes. La conséquence est que

les mauvaises herbes causent des pertes substantielles de récolte. L'utilisation des herbicides comme alternative au sarclage manuel est une contrainte par leur non disponibilité et leurs coûts prohibitifs, y compris les coûts des appareils de traitements. Les technologies de gestion des mauvaises herbes ont connu un faible taux d'utilisation en milieu paysan (par exemple l'utilisation de *Mucuna* spp., herbicides, variétés tolérantes ou résistantes). Les stratégies de gestion de chiendent des producteurs comprennent l'excavation des rhizomes de chiendent. Cette méthode est consommatrice de main d'œuvre (par exemple 175 hommes jour par hectare). Les producteurs ont changé du sans labour au billonnage, une pratique qui recycle les éléments nutritifs et réduit l'invasion des mauvaises herbes. A Damè-Wogon, les producteurs utilisent des méthodes intégrées comprenant le billonnage, et le semis de variétés de niébé à port buissonnant pour étouffer/éliminer le chiendent et pour augmenter le rendement de la culture de maïs dans une rotation niébé-maïs. Les producteurs à Somè, comme systèmes de gestion de culture, ont développé une gamme/série de mesures incluant différentes dates de semis, la rotation et l'association de cultures avec les légumineuses. Ces pratiques sont supposées accroître la production, et en même temps réduire l'interférence de *Striga*. La transplantation de sorgho était utilisée pour mieux gérer le calendrier agricole, non pas comme une méthode de contrôle de *Striga*.

Le chapitre 4 décrit comment différents acteurs (producteurs, gouvernants et chercheurs) ont socialement construit les mauvaises herbes. La recherche des archives, la revue de littérature, les questionnaires informels et semi structurés et une observation participante étaient utilisés pour mieux comprendre comment les différents acteurs ont perçu et ont réagi aux problèmes des mauvaises herbes. L'analyse des données est axée sur la pression démographique sur les terres, les technologies développées par les producteurs et les chercheurs, et le niveau d'adoption des technologies recommandées. Les noms attribués aux mauvaises herbes par les producteurs furent analysés. La valorisation des mauvaises herbes a été évaluée. Les dimensions sociales des mauvaises herbes ont été analysées comme un élément majeur du cercle vicieux de la pauvreté en milieu rural. Les résultats ont montré que la nouvelle génération est en train de vivre avec acuité une pénurie foncière et que le chiendent aussi bien que les espèces de *Striga* sont devenus des contraintes à la production agricole durant les vingt dernières années. Les noms indigènes données aux mauvaises herbes par les producteurs sont basés sur les difficultés de leur gestion et les pertes de récolte qu'elles occasionnent. Les mauvaises herbes sont aussi utilisées comme matériaux de construction et comme source de revenu (par exemple le chiendent), comme légume feuilles ou aliment du bétail et comme des plantes médicinales. Plusieurs espèces de mauvaises herbes sont des indicateurs de fertilité du sol. L'introduction des cultures de rente (tels que le coton et le palmier à huile ont eu pour conséquence la désintégration de l'organisation sociale traditionnelle et l'augmentation des coûts de main d'œuvre. Les problèmes des mauvaises herbes contraignent les producteurs aux ressources limitées à confier leurs enfants aux personnes plus nanties. Ce phénomène appelé *vidomègon* réduit la main d'œuvre disponible pour la gestion manuelle des mauvaises herbes (sarclage). Les femmes souffrent plus que les hommes à cause du mode de faire valoir de la terre.

L'administration coloniale, le second acteur que nous avons examiné, a considéré les mauvaises herbes comme une contrainte dans les plantations, mais a accordé peu d'intérêt aux mauvaises herbes dans les systèmes de production des cultures vivrières.

Récemment, la recherche agricole, le troisième acteur a reconnu les mauvaises herbes comme une contrainte majeure à la production agricole, mais les techniques de gestion de mauvaises herbes développées n'étaient pas adaptées aux systèmes de culture des producteurs. Cette différence de constructions (conceptualisation) des mauvaises herbes par les producteurs et les chercheurs nous a permis de nous engager dans une expérimentation collaborative et un apprentissage conjoint avec les producteurs afin de développer des stratégies de gestion de chiendent et de *Striga* spp. qu'ils désirent et peuvent utiliser.

Les technologies endogènes de gestion du chiendent développées par les producteurs étaient évaluées lors d'une expérimentation conjointe et un apprentissage par découverte/ expérience à Damè-Wogon, Commune de Bonou dans le département de l'Ouémé (Chapitre 5). Nous avons suggéré d'améliorer les pratiques de gestion du chiendent comprenant le labour et le sarclage profonds, le semis du niébé ou du pois d'Angole à forte densité, le traitement des plants de niébé avec des pesticides botaniques, et un labour profond pour incorporer dans le sol les résidus de récolte de niébé pour améliorer le rendement de la culture suivante de maïs. Ces nouvelles pratiques consomment plus de main d'œuvre comparativement aux pratiques originales des producteurs. Cinq différents cultivars de niébé et deux cultivars de pois d'Angole étaient testés pour la suppression du chiendent, le rendement grain, et l'augmentation du rendement de la culture de maïs. La biomasse des souches et rhizomes du chiendent au niveau du traitement témoin ont augmenté de 31 et 17 % par mois respectivement, tandis que ces biomasses connaissent une baisse significative au niveau de tous les autres traitements. La pratique traditionnelle des producteurs était significativement moins efficace que les pratiques améliorées. Les variétés tardives et rampantes de niébé ont mieux réduit la densité du chiendent comparativement aux variétés précoces et érigées. La relation entre la masse des feuilles de niébé et la suppression de rhizome était hautement significative. Cependant, une corrélation négative a été observée entre la masse de feuilles de niébé et le rendement grain du niébé. Une corrélation positive et hautement significative était obtenue entre la masse de feuilles de niébé et le rendement du maïs, et le rendement de maïs était négativement corrélé avec le rendement du niébé. Afin de passer la période de soudure, les producteurs optent pour le rendement du niébé au détriment de la suppression du chiendent et l'amélioration de la fertilité du sol

Les producteurs préfèrent le cultivar précoce et érigé *wan* par rapport aux autres cultivars. Apparemment les facteurs socio-économiques (aliment, prix de vente des différents cultivars de niébé) ont plus d'importance/priorité que les facteurs techniques liés à la fertilité du sol et la suppression du chiendent. Les producteurs aussi préfèrent le cultivar tardif de pois d'Angole comparativement au cultivar précoce. Le taux marginal de rentabilité de la variété de niébé *wan* était trois fois supérieur à celui du pois d'Angole, ce qui est conforme à la préférence des producteurs. Tandis que le pois d'Angole tardif a un taux marginal de rentabilité acceptable, le pois d'Angole ne convient pas au système de culture, parce que la culture de la variété tardive oblige les producteurs à renoncer à une récolte, dans une région à saisons de pluies où les paysans font habituellement deux récoltes par an. Présentement il n' y a aussi aucun débouché pour le pois d'Angole. Alors que la pratique améliorée de gestion du chiendent était plus consommatrice de main d'œuvre que leur pratique originale, les producteurs, ont choisi celle qui est améliorée, affirmant qu'elle leur a permis de graduellement mettre en valeur les terres qu'ils avaient abandonnées à cause de l'infestation du chiendent.

Une approche de recherche similaire était mise en œuvre pour évaluer des stratégies intégrées de gestion des cultures dans des systèmes permanents d'utilisation de la terre dans deux hameaux du village de Somè localisé dans la commune de Za-Kpota, dans le département du Zou. Les hameaux diffèrent par le capital naturel (degré de baisse de fertilité du sol) social et humain (expérience antérieure avec la recherche, y compris les essais de fertilisation). Les rendements extrêmement faibles obtenus dans le hameau central de Somè, comparé à ceux du hameau Assiankpa ont suggéré la nécessité de mesures extérieures de gestion intégrée de culture parce que dans ces conditions, la dynamique locale serait insuffisante pour augmenter les opportunités. En prélude à l'évaluation des différentes technologies susceptibles d'augmenter les rendements de culture (céréales et niébé) et décroître l'incidence de *Striga*, nous nous sommes engagés dans un apprentissage conjoint, qui a permis aux producteurs de reconnaître la spécificité des hôtes des espèces de *Striga* et de comprendre le cycle biologique du parasite. Les producteurs étaient aussi informés du mécanisme par lequel le *Striga* se dissémine. Une expérimentation comprenant différentes dates de semis de niébé comme moyen d'échapper aux dégâts de *Striga gesnerioides* montre l'importance des contraintes auxquelles font face les producteurs. Le semis précoce aussi bien que le semis tardif de niébé implique un grand risque de perte de rendement due aux aléas climatiques et à la faible efficacité d'utilisation de la pluviométrie par la culture. Comme conséquence, les producteurs sont presque contraints de synchroniser le cycle végétatif du niébé avec celui de son parasite. Une expérimentation conduite en vue de tester l'efficacité/impact de divers types de transplantation du sorgho sur le rendement de céréale et la réduction de l'interférence de *Striga hermonthica* a montré que les plants de sorgho issus des pépinières ayant reçu une application de fumure minérale et de matière organique étaient les plus efficaces. Le semis direct tardif de sorgho a également eu pour résultat une faible interférence de *Striga*, mais les rendements de sorgho étaient extrêmement bas à cause de l'insuffisance des précipitations et de la faible efficacité d'utilisation de la pluviométrie par les plants de sorgho. Cependant, la stratégie la plus efficace permettant l'augmentation de la fertilité du sol paraissait n'être pas à la portée des producteurs, parce que les engrais minéraux sont assez coûteux (et ne sont souvent même pas disponibles) et le transport de la matière organique exige une main d'œuvre importante. Les producteurs ont par conséquent préféré les pépinières installées sur des parcelles fertiles non encore infestées par le *Striga*. Tandis que la transplantation du sorgho est aussi coûteuse en main d'œuvre, c'est une technologie simple peu coûteuse, efficace et adaptée aux conditions des petits producteurs. Une expérimentation incluant diverses légumineuses (qui augmentent la fertilité du sol et pouvant servir de faux hôtes qui causent une germination suicidaire de *S. hermonthica*) a indiqué que la performance des légumineuses était fortement limitée par le niveau très bas de la fertilité du sol. De plus ceci a révélé que le problème de *Striga* peut seulement être résolu avec succès si les niveaux de fertilité du sol sont substantiellement améliorés. Nous avons aussi conclu qu'un contrôle efficace des espèces de *Striga* nécessite une approche intégrée et collective qui implique la communauté entière. Ceci est mieux réalisé à travers les approches participatives telles que le développement participatif de technologie et les champs écoles paysans.

Cette étude sur la gestion des mauvaises herbes a utilisé une approche ascendante ayant comme point de départ les connaissances locales (du bas vers le haut) contrairement à une approche dirigiste, ce qui a encouragé les producteurs à articuler leur demande, à exprimer leurs espérances et à influencer le processus de recherche sur la base de leur pratiques et connaissances locales. Dans le chapitre 7, nous décrivons une autoévaluation des producteurs en utilisant l'approche du mieux-être durable. Au nombre des cinq capitaux, seuls les capitaux humain et social étaient évalués par une approche diachronique. Les producteurs de Damè- Wogon et ceux des deux hameaux de Somè ont indiqué une augmentation dans le capital humain (aptitude et la connaissance) et le capital social (confiance en soi et organisation). Nous discutons aussi des forces et faiblesses de l'approche utilisée pour déterminer l'impact du projet de recherche sur le mieux-être durable rapporté dans cette dissertation à travers l'autoévaluation des producteurs.

Samenvatting

De bevolkingsgroei in Benin en andere landen in Afrika ten zuiden van de Sahara heeft geleid tot een grotere druk op land dat geschikt is voor landbouw. Dit heeft ertoe geleid dat kleinschalige boeren gedwongen zijn marginale gronden te ontginnen en de braakperiode te verkorten. Doordat de periode van braak onkruiden onderdrukt en de bodemvruchtbaarheid herstelt, heeft deze verschuiving naar meer permanent landgebruik geleid tot de opkomst van nieuwe onkruiden. Op hun beurt zijn deze nieuwe onkruiden weer een belangrijke factor voor verdere intensivering van het landgebruik. Kleinschalige boeren worden geconfronteerd met aan aantal beperkingen, zoals het gebrek aan beschikbare kunstmest en onkruidbestrijdingsmiddelen (of hoge kosten van deze middelen wanneer ze wel beschikbaar zijn) en een toegenomen behoefte aan en kosten van arbeid. Klimaatverandering (lagere hoeveelheden neerslag of een minder voorspelbaar neerslagpatroon; of een lagere efficiëntie waarmee landbouwgewassen gebruik maken van die regenval) leidt tot achterblijvende gewasgroei, sterkere concurrentie tussen gewas en onkruid, en uiteindelijk lagere gewasopbrengst. Lage prijzen voor landbouwproducten en een beperkte investering in de productie houden boeren in een vicieuze armoedecirkel.

Landbouwkundig onderzoek heeft slechts een beperkte invloed gehad op de levensomstandigheden van boeren. Dit was het gevolg van een ongeschikte, lineaire, top-down onderzoeksbenadering naar technologieën voor kleinschalige boeren die in een complex en risicovol milieu moeten opereren. Om het effect van onderzoek op de levensomstandigheden van kleinschalige boeren te verbeteren, hanteert deze studie aan onkruidbeheersing, die werd uitgevoerd in het kader van het programma Convergentie van Wetenschappen (CoS) het uitgangspunt dat landbouwkundig onderzoek transdisciplinair moet zijn om de effectiviteit, geschiktheid en aanvaardbaarheid van de ontwikkelde technologieën te verbeteren. Deze transdisciplinaire benadering probeert biologische en sociale wetenschappen te integreren, evenals moderne wetenschap met locale / inheemse kennis. De nadruk werd gelegd op betrokkenheid van kleinschalige boeren om hen in staat te stellen het onderzoekproces te beïnvloeden. Dit werd bereikt door interactief leren van geïntegreerd beheer van landbouwgewassen en onkruiden. Deze studie nam de locale beheerspraktijken tot uitgangspunt, om op die manier veranderingen te stimuleren in de teeltpraktijken van boeren. Voorts documenteerde en evalueerde deze studie de betekenis van samenwerking in onderzoek als een betere benadering voor het ontwikkelen van technologieën, en richtte zich daarbij op menselijk en sociaal kapitaal, twee essentiële voorwaarden om duurzame levensomstandigheden te creëren.

Het onderzoek omvatte (1) technografische studies die werden uitgevoerd door een multidisciplinair team om keuzes te maken in de thema's, de relevante actoren, onderzoeksgebieden en boerengemeenschappen die betrokken zouden kunnen worden in actie-onderzoek; (2) diagnostische studies die werden uitgevoerd in de verschillende agro-ecologische zones in Benin om de pre-analytische keuze, die voordien al door de onderzoeker gemaakt was om aan onkruid te werken, te valideren en om het onderzoek te verankeren in de behoeftes van de boeren; (3) gezamenlijk experimenteren via leren-door-zelf-ontdekken met boerenstudiegroepen in twee dorpen. Het voornaamste doel van het gezamenlijk onderzoekproces was om de capaciteit van boeren te versterken door de participatieve ontwikkeling van onkruidbeheersingstechnologieën die effectief en voor boeren aanvaardbaar zijn en die slechts geringe investeringen in geld en arbeid zouden vergen. De studie werd uitgevoerd in Damè-Wogon (district Bonou) en Somè (district Za-Kpota), twee dorpen die gelegen zijn in de zuidelijke agro-ecologische zone (hoofdstuk 2). In deze dorpen zijn speergras (*Imperata cylindrica*) en striga (*Striga hermonthica* en *S. gesnerioides*) de belangrijkste onkruiden, die verantwoordelijk zijn voor zeer aanzienlijke opbrengstverliezen en die er mede voor verantwoordelijk zijn dat boeren in deze schijnbare vicieuze armoedecirkel blijven.

In hoofdstuk 2 beschrijf ik het kader waarin ik verschillende onderzoeksparadigma's analyseer waarbinnen technologieën voor onkruidbeheersing werden ontwikkeld en verspreid. Deze aanbod-gedreven, top-down benaderingen worden thans als ongeschikt beschouwd om onder de omstandigheden van de boeren ter plaatse gebruikt te kunnen worden. De ontwikkelde technologieën voor onkruidbeheersing hielden geen rekening met de sociale en economische dimensies van onkruidproblemen, zoals arbeid (beschikbaarheid, kosten, het vernederende karakter van de hele dag op je knieën onkruid verwijderen dat sneller lijkt te groeien dan je kunt wieden) en marktprijzen van landbouwproducten. Ondanks veranderingen in de richting van meer participatieve benaderingen (bijvoorbeeld bedrijfssysteemonderzoek (Farming Systems Research) en participatieve technologie-ontwikkeling (Participatory Technology Development)) hebben boeren zich het onderzoekproces nog niet toegeëigend. De nadruk in het CoS-programma werd gelegd op democratisering van wetenschap en het bewerkstelligen van boerenmacht om de zelfstandigheid van boeren te vergroten.

De diagnostische studie (hoofdstuk 3) kwam tot de conclusie dat onkruiden inderdaad een belangrijke belemmering zijn voor de productie van landbouwgewassen, met name in gebieden waar de druk op voor landbouw geschikt land groot is. De meest problematische onkruiden waren speergras en de parasitaire onkruiden *Striga hermonthica* (op granen zoals sorghum en maïs) en *S. gesnerioides* (op koeienerwt). In de agro-ecologische overgangszone en in de noordelijke zone bleken onkruidproblemen minder ernstig te zijn dan in de zuidelijke zone doordat boeren daar nog steeds zwerflandbouw kunnen bedrijven met braakperioden die variëren van vier tot tien jaar. De meest voorkomende manier om onkruiden te beheersen bestond uit wieden (met de hand of schoffel), maar dit heeft tot gevolg dat boeren meer dan 50% van hun tijd besteden aan wieden. Doordat er gebrek is aan eigen arbeid (mede doordat kinderen tegenwoordig vaker naar school gaan) zijn de kosten om arbeid in te huren hoog. Deze kosten hebben tot gevolg dat boeren 'strategisch' wieden, hoewel dat leidt tot minder vaak wieden dan nodig is om onkruid te beheersen. Het gevolg is dat onkruid leidt tot verdere opbrengstverliezen van landbouwgewassen. Het gebruik van herbiciden als alternatief wordt beperkt doordat deze herbiciden hetzij in het geheel niet beschikbaar zijn, hetzij doordat de kosten, wanneer ze wel beschikbaar zijn, hoog zijn. De door het onderzoek en voorlichting aanbevolen technologieën voor onkruidbestrijding (het gebruik van fluweelboon (mucuna) als bodembedekker, herbiciden, het gebruik van tolerante of resistente gewasrassen) zijn over het algemeen door boeren niet overgenomen. De manier waarop boeren speergras bestrijden bestaat uit het uitgraven van de ondergrondse uitlopers. Deze methode is erg arbeidsintensief (175 mensdagen per hectare). Boeren gaan tegenwoordig over tot het aanleggen van bedden, een praktijk die voedingsstoffen recyclet en die onkruiden onderdrukt. In Damè-Wogon gebruiken boeren methoden die bestaan uit het aanleggen van bedden en het planten van rassen van koeienerwt met veel bladmateriaal om speergras te onderdrukken en om de opbrengst van maïs als volggewas te vergroten. Boeren in Somè hebben, als deel van hun landbouwpraktijken, een reeks maatregelen ontwikkeld tegen striga die bestaan uit het variëren van het tijdstip waarop gewassen geplant worden (om te voorkomen dat de kieming van gewas en striga synchroon verlopen), vruchtwisseling tussen en mengteelten met granen en vlinderbloemigen. Deze praktijken beogen zowel te leiden tot een verhoging van de landbouwproductie als tot een onderdrukking van striga. Het overplanten van jonge sorghumplantjes werd toegepast als manier om arbeid beter in de tijd te kunnen spreiden, maar bleek ook geschikt te zijn als manier om striga te verminderen.

Hoofdstuk 4 geeft een beschrijving van de manier waarin verschillende sociale groepen (boeren, overheidsfunctionarissen, onderzoekers) het begrip onkruid hebben geconceptualiseerd (sociale constructie). Archief- en literatuuronderzoek, informele interviews, en observatie van betrokkenen werden gebruikt om beter te begrijpen hoe deze actoren het onkruidprobleem hebben waargenomen, geïnterpreteerd en daarop gereageerd. De analyse van deze gegevens wees op het belang van de toegenomen druk op land (als gevolg van de bevolkingstoename), de technologie-ontwikkeling door onderzoekers en boeren, en de mate waarin aanbevolen technologieën werden overgenomen. Sommige onkruiden bleken ook hun positieve kanten te hebben. Onkruiden kunnen ook gebruikt worden als materiaal om daken mee te bedekken en dus als bron van inkomsten (speergras), als groente, als voedsel voor vee, en als medicijn. Sommige onkruiden worden ook gebruikt als indicator voor vruchtbare bodems. De sociale dimensie van onkruiden werd geanalyseerd als een zeer belangrijk element in de vicieuze cirkel van armoede op het platteland. De huidige generatie landbouwers wordt geconfronteerd met een acuut gebrek aan (vruchtbaar) land. Daardoor hebben speergras en striga in de laatste twintig jaar veel grotere negatieve effecten gekregen op de landbouwproductie. De namen die boeren aan speergras en striga geven weerspiegelen de mate waarin beide lastig te bestrijden en beheersen zijn en de mate waarin zij verantwoordelijk zijn voor opbrengstverliezen. De introductie van exportgewassen (bijvoorbeeld katoen en oliepalm) hadden een uit elkaar vallen van de traditionele sociale organisatie tot gevolg en leidde tot een toename van de kosten voor arbeid. De onkruidproblematiek dwingt de allerarmste boeren om de verzorging van hun kinderen 'toe te vertrouwen' aan rijkere mensen, in de grote steden of in het buitenland. Dit verschijnsel (*vidomègon*), soms bijna een vorm van kinderslavernij, leidt tot een afname van beschikbare (kinder-)arbeid. Vrouwen hebben meer te lijden van onkruidproblemen dan mannen als gevolg van het dominante systeem van landgebruiksrechten, waarbij vrouwen meestal de minst vruchtbare gronden gebruiken.

Het (koloniale) bestuur, de tweede door ons bestudeerde partij, had wel oog voor onkruiden als belangrijk probleem in de plantages van commerciële exportgewassen, maar toonde vrijwel geen belangstelling voor onkruiden in de landbouwsystemen waarin voedsel voor de eigen bevolking werd verbouwd. Na de onafhankelijkheid van Benin kwam hierin overigens weinig verandering. Landbouwkundig onderzoek, de derde partij, heeft eerst recent onkruid erkend als belangrijke beperkende factor voor de productie van voedselgewasen. De door het onderzoek ontwikkelde onkruidbestrijdingspraktijken bleken echter niet passend voor deze landbouwsystemen. Het niet op elkaar aansluiten van deze verschillende constructies of conceptualiseringen van onkruid door boeren en onderzoekers was voor ons een belangrijke motivatie om gemeenschappelijke experimenten en gemeenschappelijk leren op te zetten, om via die weg gezamenlijk strategieën te ontwikkelen om speergras en striga te bestrijden die boeren wenselijk achten en ook kunnen gebruiken.

De locale boerentechnologieën om speergras te beheersen werden getest in een gemeenschappelijk experiment en gezamenlijk leren-door-zelf-ontdekken in Damè-Wogon (hoofdstuk 5). Door ons werd een verbeterde methode om speergras te beheersen voorgesteld die bestaat uit hoge bedden en diep wieden, het zaaien van koeienerwt of duivenerwt in hogere dichtheid dan gebruikelijk, het behandelen van koeienerwt met botanische pesticiden, en het aanleggen van hoge bedden om gewasresten van koeienerwt te incorporeren ten behoeve van het volggewas maïs. Deze nieuwe praktijken zijn aanmerkelijk arbeidsintensiever dan de bestaande boerenpraktijk. Vijf verschillende rassen van koeienerwt en twee rassen van duivenerwt werden getest voor hun opbrengst, de mate van onderdrukking van speergras, en de opbrengstverhoging van het volggewas maïs. Zonder onkruidbestrijding nam het aantal scheuten en ondergrondse uitlopers van speergras maandelijks toe met respectievelijk 31% en 17%, terwijl in alle proefvakken waar onkruidbestrijding werd toegepast speergras significant afnam, zowel boven- als ondergronds. De traditionele boerenmethode was significant minder effectief dan de verbeterde methode. Kruipende, bodembedekkende rassen van koeienerwt die laat rijpen onderdrukten speergras beter dan rechtopstaande, vroegrijpende rassen. Er bleek een significant positief verband te bestaan tussen de bladmassa van koeienerwt en de mate van onderdrukking van speergras. Maar de bladmassa van koeienerwt bleek significant negatief gecorreleerd met de opbrengst van koeienerwt. Er bleek voorts een significant positief verband tussen bladmassa van koeienerwt en opbrengst van maïs als volggewas, en een significant negatief verband tussen de opbrengst van koeienerwt en de opbrengst van maïs. Boeren moeten dus een afweging maken tussen de opbrengst van koeienerwt (om de periode van voedseltekort te kunnen overbruggen) en de onderdrukking van speergras en de verbetering van de bodemvruchtbaarheid. Boeren bleken de voorkeur te geve aan het vroegrijpende, rechtopgroeiende koeienerwtenras *wan* boven de andere rassen. Blijkbaar zijn sociaal-economische factoren (overbruggen van de periode van voedselschaarste, marktprijzen voor de verschillende koeienerwtenrassen) belangrijker dan de technische factoren die verband houden met bodemvruchtbaarheid en het bestrijden van speergras. Boeren gaven de voorkeur aan een laatrijpend ras van duivenerwt boven een vroegrijpend ras. Opbrengst na investering in koeienerwt (*wan*) was drie keer zo hoog als voor duivenerwt, en dit is in overeenstemming met de voorkeur die boeren hebben voor koeienerwt boven duivenerwt. Hoewel de opbrengst na investering in duivenerwt acceptabel was, bleek duivenerwt geen nis te vullen in het plaatselijk landbouwsysteem, doordat het telen van een laatrijpend ras van duivenerwt tot gevolg heeft dat boeren één groeiseizoen moeten 'overslaan', hetgeen zij zich niet kunnen en willen veroorloven. Op dit moment is er ook nauwelijks een markt voor duivenerwt. Hoewel de verbeterde methode om speergras te bestrijden veel arbeidsintensiever was dan de door de boeren gebruikte methode, namen boeren de nieuwe methode toch over. Ze stelden dat deze verbeterde methode het hun mogelijk maakt om geleidelijk aan land opnieuw in cultuur te nemen dat ze als gevolg van de grote hoeveelheid speergras uit productie hadden genomen.

Een vergelijkbare onderzoeksbenadering werd gebruikt om geïntegreerde landbouw-beheersystemen onder omstandigheden van permanent landgebruik te evalueren in twee nederzettingen van Somè (hoofdstuk 6). Beide nederzettingen waren verschillend in de mate van natuurlijk kapitaal (de mate van bodemuitputting), en sociaal en menselijk kapitaal (de mate waarin ze hebben samengewerkt met onderzoekers, waaronder experimenten met kunstmest). De extreem lage gewasopbrengst in Somè central, in vergelijking met Assiankpa, gaf zeer sterke aanwijzingen voor de noodzaak tot externe ondersteuning voor geïntegreerd beheer van grond en gewas, doordat onder de daar heersende omstandigheden de locale dynamieken onvoldoende zijn om tot innovatie te komen. Voordat we verschillende methoden konden testen die zouden kunnen bijdragen tot hogere gewasopbrengst (granen en koeienerwt) en tot lagere aantallen striga, startten we een gezamenlijk leerproces, waarbij boeren in staat werden gesteld te ontdekken dat verschillende soorten striga verbonden zijn met verschillende gastheren en waarbij boeren de levenscyclus van striga ontdekten. Boeren ontdekten ook hoe striga zich kan verspreiden. Een proef waarop koeienerwt op verschillende tijdstippen werd geplant, om koeienerwt de kans te geven te ontsnappen aan de kiemende zaden van *Striga gesnerioides*, liet zien hoe groot de beperkingen zijn waarmee boeren geconfronteerd worden bij hun gewasbeheer. Zowel vroeg als laat zaaien van koeienerwt zijn niet zonder risico voor volledig opbrengstverlies, als gevolg van het onvoorspelbare klimaat en de lage efficiëntie waarmee het gewas regenwater kan gebruiken in deze gedegradeerde bodems. Het uiteindelijke gevolg is dat boeren gedwongen worden de levenscyclus van koeienerwt en striga gelijk op te laten lopen en dat ontsnapping in de tijd voor koeienerwt dus geen optie is. Een proef om de effectiviteit te testen van verschillende manieren van overplanten van zaailingen van sorghum liet zien dat het direct overplanten van zaailingen vanuit kiembedden waaraan compost en kunstmest was toegevoegd het meest effectief was, dwz leidde tot de hoogste sorghumopbrengst en laagste aantallen striga. Lage aantallen striga werden ook gevonden wanneer het zaaien van sorghum werd uitgesteld, maar in dat geval was de sorghumopbrengst eveneens extreem laag als gevolg van droogte en lage waterverbruiksefficiëntie van sorghum. De meest succesvolle strategie die boeren kunnen toepassen, namelijk het verhogen van de bodemvruchtbaarheid, is helaas nauwelijks haalbaar voor boeren, doordat kunstmest te duur is (als kunstmest al verkrijgbaar is) en het transporteren van compost (die overigens slechts beperkt beschikbaar is) te arbeidsintensief. Om die reden geven de boeren de voorkeur aan het aanleggen van kiembedden in vruchtbare, striga-vrije plekken. Hoewel ook deze praktijk erg arbeidsintensief is, is ze tegelijkertijd eenvoudig en goedkoop, en effectief en aangepast aan de omstandigheden voor deze kleinschalige boeren. Een proef met verschillende vlinderbloemigen (die kunnen leiden tot verhoging van de bodemvruchtbaarheid via stikstofbinding en die ook kunnen fungeren als vanggewas voor striga doordat ze zelfmoordkieming van strigazaden veroorzaken) liet zien dat de groei van deze vlinderbloemigen sterk beperkt werd door de lage bodemvruchtbaarheid. Opnieuw gaf dat dus aan dat het strigaprobleem alleen met succes kan worden aangepakt als de bodemvruchtbaarheid aanzienlijk toeneemt. We kwamen eveneens tot de conclusie dat een effectieve bestrijding van striga collectieve actie noodzakelijk maakt die de hele boerengemeenschap aangaat. Zo'n collectieve actie kan het best bewerkstelligd worden via participatieve benaderingen zoals participatieve technologie-ontwikkeling en boerenveldscholen (Farmer Field Schools).

De studie over onkruidbeheersing maakte gebruik van een bottom-up benadering welke boeren stimuleerde om hun behoeftes en verwachtingen te articuleren, en invloed te hebben op het onderzoekproces op basis van hun eigen praktijken. In hoofdstuk 7 beschrijven we een zelfevaluatie door de boeren, met gebruikmaking van de benadering van de duurzame levensomstandigheden (Sustainable Livelihoods Approach). Van de vijf kapitalen werden alleen veranderingen in menselijk en sociaal kapitaal bepaald aan het einde van de experimenten. De boeren in Damè-Wogon en beide nederzettingen van Somè gaven aan dat hun menselijk kapitaal (vaardigheden en kennis) en hun sociaal kapitaal (zelfvertrouwen, organisatie) waren toegenomen. In dat hoofdstuk bespreken we ook de sterke en zwakke punten van deze evaluatiemethode waarmee het effect van onderzoekprojecten, zoals het hier uitgevoerde onderzoek, kan worden vastgesteld via zelfevaluatie door boeren.

The Convergence of Sciences Programme[1]

Background

This thesis is the outcome of a project within the programme "*Convergence of Sciences: inclusive technology innovation processes for better integrated crop and soil management*" (CoS). This programme takes off from the observation that West African farmers derive sub-optimal benefit from formal agricultural science. One important reason for the limited contribution of science to poverty alleviation is the conventional, often tacit, linear perspective on the role of science in innovation, i.e. that scientists first discover or reveal objectively true knowledge, applied scientists transform it into the best technical means to increase productivity and resource efficiency, extension then delivers these technical means to the 'ultimate users', and farmers adopt and diffuse the 'innovations'.

In order to find more efficient and effective models for agricultural technology development the CoS programme analysed participatory innovation processes. Efficient and effective are defined in terms of the inclusion of stakeholders in the research project, and of situating the research in the context of the needs and the opportunities of farmers. In this way stakeholders become the owners of the research process. Innovation is considered the emergent property of an interaction among different stakeholders in agricultural development. Depending on the situation, stakeholders might be village women engaged in a local experiment, but they might also comprise stakeholders such as researchers, farmers, (agri)-businessmen and local government agents.

To make science more beneficial for the rural poor, the CoS programme believes that convergence is needed in three dimensions: between natural and social scientists, between societal stakeholders (including farmers), and between institutions. Assumptions made by CoS are that for research to make an impact in sub-Saharan Africa: most farmers have very small windows of opportunities, farmers are innovative, indigenous knowledge is important, there is a high pressure on natural resources, the market for selling surplus is limited, farmers have little political clout, government preys on farmers for revenue, and institutional and policy support is lacking. To allow '*ex-ante* impact assessment' and ensure that agricultural research is designed to suit the opportunities, conditions and preferences of resource-poor farmers, CoS pioneered a new context-method-outcome configuration[2] using methods of technography and diagnostic studies.

[1] Hounkonnou, D., D.K. Kossou, T.W. Kuyper, C. Leeuwis, P. Richards, N.G. Röling, O.Sakyi-Dawson, and A. van Huis, 2006. Convergence of sciences: the management of agricultural research for small-scale farmers in Benin and Ghana. *Wageningen Journal of Life Sciences (NJAS)*, 53(3/4): 343-367.

[2] See R. Pawson and N. Tilley, 1997. *Realistic evaluation*. London: Sage Publications.

Technographic and diagnostic studies

The technographic studies explored the innovation landscape for six major crops. They were carried out by mixed teams of Beninese and Ghanaian PhD supervisors. The studies looked at the technological histories, markets, institutions, framework conditions, configurations of stakeholders, and other background factors. The main objective of these studies was to try and grasp the context for innovation in the countries in question, including appreciation of limiting as well as enabling factors.

The diagnostic studies were carried out by PhD students from Benin and Ghana. They focused in on groups of farmers in chosen localities, in response to the innovation opportunities defined during the technographic studies. The diagnostic studies tried to identify the type of agricultural research - targeting mechanisms - that would be needed to ensure that outcomes would be grounded in the opportunities and needs of these farmers. Firstly, that not only meant that research needed to be technically sound, but also that its outcomes would work in the context of the small farmers, taking into account issues such as the market, input provision, and transport availability. Secondly, the outcomes also needed to be appropriate in the context of local farming systems determined by issues such as land tenure, labour availability, and gender. Thirdly, farmers also need to be potentially interested in the outcomes taking into account their perceived opportunities, livelihood strategies, cultural inclinations, etc.

The diagnostic studies led to the CoS researchers facilitating communities of practice of farmers, researchers, scientists from national research institutes, local administrators and local chiefs. The research was designed and conducted with farmer members of the local research groups. Their active involvement led to experiments being added, adapted or revised.

It also made the researchers aware of the context in which the research was conducted. A full account of the diagnostic studies can be found in a special issue of NJAS[3].

Experimental work with farmers

After completing the diagnostic studies, the PhD students engaged in experiments with farmers on integrated pest and weed management, soil fertility, and crop genetic diversity, in each case also taking into account the institutional constraints to livelihoods. They focused on both experimental content and the design of agricultural research for development relevance. Experiments were designed and conducted together with groups of farmers, and involving all stakeholders relevant for the study. The aim was to focus on actual mechanisms of material transformation – control of pests, enhancement of soil fertility, buffering of seed systems –

[3] Struik, P.C. and J.F. Wienk (Eds.), 2005. Diagnostic studies: a research phase in the Convergence of Sciences programme. *Wageningen Journal of Life Sciences (NJAS)*, 52 (3/4): 209-448.

of direct relevance to poverty alleviation among poor or excluded farming groups. The ninth PhD student carried out comparative 'research on research' in order to formulate an interactive framework for agricultural science.

Project organization

All students were supervised by both natural and social scientists from the Netherlands and their home countries. In each country, the national coordinator was assisted by a working group from the various institutions that implemented the programme. A project steering committee of directors of the most relevant research and development organizations advised the programme. The CoS programme had a Scientific Coordination Committee of three persons, including the international coordinator from Wageningen University.

CoS had two main donors: the Interdisciplinary Research and Education Fund (INREF) of the Wageningen University in the Netherlands and the Directorate General for International Cooperation (DGIS), Ministry of Foreign Affairs of the Netherlands. Other sponsors were the FAO Global IPM Facility (FAO/GIF), the Netherlands Organization for Scientific Research (NWO), the Wageningen Graduate School Production Ecology and Resource Conservation (PE&RC), the Technical Centre for Agricultural and Rural Cooperation (CTA or ACP-EU), and the Netherlands organization for international cooperation in higher education (NUFFIC). The total funds available to the project were about € 2.2 million.

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Curriculum vitae

Pierre V. Vissoh was born in Ina (District of Bembérèkè), Benin on 20 November 1958. After completing his certificates of primary and secondary school in Logozohè (District of Savalou, Department of the Collines), he was admitted at the Collège d'Enseignement Moyen Général (CEMG) of Savalou in 1977 where he got his Baccalaureate in 1979. In 1980, he was enrolled in a military and patriotic training during the era of Marxism Leninism. Then he attended the Faculté des Sciences Agronomiques de l'Université d'Abomey-Calavi from February 1981 to December 1986 where he was rewarded with a diploma of Ingénieur Agronome in Crop Sciences. He worked as a volunteer in the reforestation project Plantation Bois de Feu au Sud-Benin from November 1987 to December 1989. He joined a R&D team at the headquarters of the Centre d'Action Régional pour le Dévéloppement Rural (CARDER) of the Atlantique Department where he studied traditional cropping systems (ESYCTRA) from May 1989 to April 1991. At the end of his contract he got a job opportunity at Sasakawa Global 2000 (SG2000), where he was responsible for the diversification programme including soil fertility restoration and reclamation of Imperata grassland using green manure cover crops (*Mucuna* spp.) and the dissemination of improved cultivars of cassava and quality protein maize. At the same time he was a resource person linking the SG2000 project to research centres (e.g. INRAB, IITA, IFDC, the World Phosphate Institute, and WARDA). In November 1992 he was granted a scholarship by the SAFE (Sasakawa Africa Fund for Extension Education) programme of SG2000, which enabled him to complete a Master of Science in Agricultural extension at the University of Ibadan, Nigeria in May 1994. From 1996 to 1998 he carried out on-farm demonstration trials to promote balanced and efficient use of fertilisers with the World Phosphate Institute (located at Casablanca, Morocco) in the different agro-ecological zones of Benin and Togo. In 2001, he was offered the opportunity to proceed to the PhD programme by the Convergence of Sciences (CoS) programme funded by INREF (Wageningen University) and DGIS (Ministry of Foreign Affairs), the Netherlands.

COMPLETED TRAINING AND SUPERVISION PROGRAMME
Pierre Vissoh

Description	Department/Institution	Year	Credits (ECTS)
I. Orientation			
Literature research	WUR	2001-2002	4
Presentation research proposal	WUR	2002	2
Social Construction of New Agricultural Technologies	Department of Social Sciences/WUR	2001	3
Ecological Aspects of Agricultural Systems	Department of Plant Sciences/WUR	2001	3
Agricultural Knowledge and Information Systems	Department of Communication Innovation Studies	2002	3
II. Research Methods and Techniques			
Methods and Techniques for Social Scientific research	Department of Social Sciences/WUR	2001	3
Methods and Techniques of Social field research	Department of Social Sciences/WUR	2002	3
Participatory approaches: FPR, PRA, PLAR, RAAKS	Department of Communication Innovation Studies	2002	2
Written English	Language Centre/WUR	2001	1
English Scientific Writing	Language Centre/WUR	2002	1
Training on Multi Stakeholder Processes	WICC/UAC	2004	1
III. Seminar attendance and presentations			
Internal seminars of Technology and Agrarian Development	Department of Social Sciences/WUR	2001-2002 2006	1
Internal seminars of Crop and Weed Ecology Group	Department of Plant Sciences/WUR	2001-2002 2006	1
Internal seminars of Communication and Innovation Studies Group	Department of Communication Innovation Studies	2001-2002 2006	1
International seminars of Convergence of Sciences	WUR/UAC/UL	2001-2005	8
Seminars organised by research institutions in Benin	INRAB, IITA, GTZ,	2002-2205	2
World Soil Issues and Sustainable development: An Agenda for Action. 40 years ISRIC- World Soil Information	WICC	2006	1
Total			40

Done at Wageningen, 9 march 2006

Pierre Vinassého Vissoh **Prof. Niels Röling**