IITA's position paper for the CP-SSA proposal development
Task force meeting, Accra, 10-14 March, 2003

Preface

This position paper lists key hypotheses, which, if implemented would increase the likelihood of adoption and impact. It is considered to be the very first step for designing a challenge program (CP) on integrated natural resource management (INRM). Implementation of NRM hypotheses has to be location-specific, because sub-Saharan Africa's (SSA) biophysical and socio-economic conditions are too diverse (Barrett et al. 2002b) for general hypotheses to be true at even many locations. These hypotheses, which provide the framework for subsequent action, must be fine-tuned once the intervention areas have been identified. Further, a truly participatory approach demands the involvement of all stakeholders right from the planning stage. This can only be achieved, when contacts with all stakeholders have been established. This will lead to modification of certain hypotheses. As noted by Hagmann et al. (2002), "INRM is a moving target", which makes it highly likely that the start-up hypotheses will need to be changed in the course of implementing the program. After all, the only sustainable approach is constant change in a fast changing world, which is particularly important for the mindset of researchers. Too many research projects in the past have been shaped by pre-conceived perceptions of problems and solutions of researchers (Collinson 2001). In the best of worlds, the public research agenda would be shaped by grass-root democratic institutions which bestow rural communities with real decision-making power. As these institutions are still sorely lacking in many parts of rural Africa, participatory approaches are best for those who struggle daily to overcome their numerous constraints, enabling them to strive towards a sustainable livelihood based on agriculture (Chambers et al. 1989).

IITA has responded to FARA's questionnaire on refining the hypotheses of the pre-proposal. Those hypotheses cover the whole spectrum that needs to be addressed in order to implement 'integrated' NRM. Building on these hypotheses, this position paper focuses – with a rigorous view – on interventions, which should have a high chance of adoption by key stakeholders and therefore impact. Any intervention that comes out of this CP and is not adopted at large scale by the relevant stakeholders must ultimately be considered a failure for the CP, unless the intervention addresses a specific niche problem. Such an approach requires the definition of recommendation domains for each intervention. Smith and Weber (1994) and Douthwaite et al. (accepted) provide examples of a workable approach, which could be combined with a soilscape approach as described by Deckers (2002).

The challenge that this program faces is the conflict between what is required and what seems achievable. Firstly, <u>integration</u> of all necessary NRM practices is key to success and policy, institutional, and infrastructural interventions are crucial components. Scherr and Hazell (1994) listed 32 necessary intervention approaches, of which 4 related to technical, 12 to institutional, and 16 to policy interventions. Yet, changes at the policy level are much more difficult to induce by the CP than technical interventions, because the former require a government with forsight, good governance, and a civil society ruled by law (Barrett et al (2002b) – truly scarce resources in SSA. Secondly, a key target group of the CP is poor farmers, who are mostly in rural areas of SSA (IFAD 2001). These areas often lack good infrastructure and access to markets. Yet, several studies emphasize that chances for adoption of NRM practices tremendously increase in areas with commercially oriented farmers (Freeman and Core, 2002, Freudenberger and Freudenberger, 2002). "In zones where farmers do not produce a commercial crop, a major challenge remains" was the only 'solution' of Kelly et al. (2002) to the problem.

Hypotheses for interventions with a high chance of adoption success

1. This CP should focus first and foremost on areas, where land pressure and liberal markets are driving intensification and commercialisation of agriculture, because chances are much higher that farmers are willing to develop, test, and adopt NRM practices, leading to desired impacts.

2. A high level of interaction, from the onset of the programme, between the farming community, the private sector, policy makers, extension agents, information managers and researchers is key to any successful, i.e. adopted, NRM intervention.

3. NRM work should start by focusing on key constraints of location-specific soil degradation as perceived by farmers, the identification of which is assisted by researchers and extension agents.

4. The adoption and impact of NRM innovations will be higher when targeting cropping systems with the highest economic or food security interest for farmers.

5. Weed, pest, and disease problems are increased by degraded or stressed soils, but integrated pest/disease/nutrient management practices, tailored to smallholder conditions, can alleviate the problems.

6. Required nutrient management of crops on degraded or stressed soils has to include other nutrients than just N-P-K, and the adoption of soil-improving N-fixing legumes, using current manual cultivation techniques, is under most circumstances limited by costly labour requirements.

7. The mechanization of cultivation techniques is likely to increase adoption of soil-conserving legumes at large-scale.

8. Improving the quantity and quality of crop by-products, available for livestock feed, will have a positive effect on the adoption of NRM practices in crop-livestock systems.

9. Scaling out and up of the above NRM interventions is most likely to be achieved if supported by effective market information and micro-credit schemes as well as decentralized policy and institutional reforms.

10. Adoption of NRM practices in land-abundant areas with limited road infrastructure and access to markets is unlikely. High value non-perishable commodities, improved germplasm for staple and new crops, adapted to soil stress and pest/disease resistant, are the choices available.

Explanations to the above hypotheses

1. Focus on land-scarce areas with good or medium market access

NRM is an investment choice (Barrett et al. 2002b), requiring the right context for adoption. Kelly at al. (2002) were unequivocal in saying that "strong economic incentives are needed to stimulate NRM adoption". Binswanger (1986) pointed out, that: " … under land abundance … farmers will simply not be very interested in fertilizers … or elaborate crop husbandry techniques, such as intensive manuring, or in land conservation techniques". Land-scarce areas with good or medium market access enable farmers to invest in NRM practices and livelihood assets, because there, farmers have greater liquidity (Wyatt 2002). Kuyvenhoven et al. (1999) recommended improvement of market functioning and reduction of transport and other transaction costs besides better access to credit, labour, information, and soil fertility enhancing inputs as necessary measures to facilitate the transition to more sustainable practices. Furthermore, urbanization rates, which are the highest of any in the world (WRI 1999), call for testing out NRM practices especially in areas supplying products to major cities (note: for non-perishable products, this is not congruent with peri-urban areas!). These areas are typically endowed with adequate population and road infrastructure. It is estimated that the cost of fixing major roads alone in SSA is over $18 billion per year (World Bank, cited in The Economist, 2002).

2. Stakeholder interaction: key for success

Development of practically all technologies beyond germplasm, adapted to stressed environments, and fertilizer/biocide use requires repeated farmer-researcher interaction as pointed out by Douthwaite (2000) and Douthwaite et al. (2001). Successful technologies are "constructed through a process of people and groups making sense of their experiences" (Douthwaite et al. in press) with proto-type technologies. Facilitating interaction (Röling 1994, Pretty and Buck, 2002) can easily be combined with training sessions, necessary for knowledge-intensive NRM (Barrett et al. 2002b). Stakeholder platforms enable also information exchange, for example on dynamic markets, which is often limited at farmer level (Foodnet 2002). Communication media popular with farmers, such as the radio, greatly enhances information exchange as has been successfully demonstrated in Uganda (Foodnet 2002).

3. Focus on key constraints as perceived by farmers

Soil degradation is location-specific and can be caused by soil-borne pests and diseases (IITA/DFID 2002, Sikora et al. 1994), excessive nutrient losses to the system (Smaling et al. 1997), erosion (Lal 1995, Aune 1995), or water deficiency through soil crusting (Reij et al. 1996). Simple interventions should be developed first with smallholder farmers, because they have the highest chance of adoption. This was reported by Shapiro and Sanders (2002) for water conservation techniques in semi-arid areas, by Hagmann and Chuma (2002) for soil erosion in Zimbabwe, and by IITA/DFID (2002) for soil-borne *Striga* problems. In contrast, more complicated interventions to improve water availability require policy adjustments, for example in terms of land tenure, which are more difficult to achieve. Hatibu et al. (2002) reported that existing policies in Tanzania do not even recognize the need for water management.

Simple modifications of crop management can start with, for example, seeding maize in rows rather than at random. This can go along with the use of improved germplasm, adapted to stressed soils, and other inputs. A large number of farmers picked up these 3 key elements in maize-growing areas in the forest-savannah transition zone of Kumasi, Ghana (P. Osei-Bonsu, pers. commun.). In this case, the use of glyphosate for weed control, was preferred by farmers over fertilizer use. Such a first step of intensification lays often the ground for more sophisticated soil conservation measures, such as integration of soil-conserving legumes. For example, Peter Osei-Bonsu of CRI in Ghana now tests out with farmers the integration of Mucuna into intensive maize systems. Similar simple improvements have also been adopted by a large number of farmers in the northern Guinea savannah of Nigeria, where a sizeable number of farmers use mineral fertilizer in areas with limited supply constraints (Manyong et al. 2002). Manure application or kraaling is used by many farmers to combat nutrient depletion in semi-arid areas, where crop and livestock husbandry is practiced (Ndlovu and Mugabe 2002, Freeman and Coe 2002). These existing farmer practices can be easily intensified through improved crop by-products, such as adapted sorghum and dual-purpose cowpea or soybean germplasm (Inaizumi et al. 1999). 'Best-bet' options, proposed by researchers, are quickly picked up by the farming community, if the intervention is targeted towards farmer circumstances.

4. Tackle cropping systems with the highest economic or food security interest first

A cash incentive (Kelly et al. 2002) or lack of food security in land-scarce areas (Freeman and Coe 2002), are vital for the adoption of even simple NRM practices, such as fertilizer application. Brader (2002) reported high adoption rates for adapted improved germplasm in West Africa, because its use is knowledge-extensive. All the new knowledge is in the seed (Douthwaite 2002) and can be easily integrated into existing farm management, the reason why farmers pick it up first (Mutsaers et al. 1995). For high-value crops, farmers already use inputs, even if all the other crops are traditionally managed. For example, in the forest zone of southern Cameroon, where purchased inputs are rarely used on staple crops, high-value horticultural crops, such as traditional leafy vegetables, tomatoes, okra and green pepper are fertilized and pesticides regularly applied (Gockowski and Numbem, in press). The incentive to earn income is a strong "pull" for intensification and the application of more sophisticated NRM technologies. Fresh cassava, the real market price of which has increased annually since 1999 by 15% on the Yaoundé market (S. Dury, unpublished data) has become the crop with the highest total market value in that area. Some farmers intensively grow and market this crop, which should be incentive enough to use NRM practices, although, traditionally, cassava is perceived in Africa as a 'no-input' crop (Nweke et al. 2002). Plantain in the humid zone is a high value crop but is subject to declining yields as fertility rents achieved from the conversion of tropical forests are used up overtime (Temple and Achard 1996) and can thus be targeted for NRM practices. The same was reported by Ruf (1996) for tree crop systems, such as cocoa, oil palm, rubber, and coffee. Also, as perennial crops, often grown on acid soils, they are the ideal target application of medium- to low-grade West African rock phosphate, if P turns out to be a limiting nutrient and transportation costs are not excessive. High-value commodities can be profitably cultivated and marketed over a larger spatial domain relative to low-value crops, because per unit marketing costs are a smaller proportion of the total value of the commodity.

5. Integrated pest/disease/nutrient management of degraded soils

"Soil fertility depletion in smallholder farms is increasingly being recognized as the fundamental biophysical root cause responsible for declining per capita food production in Africa [several references quoted]. By fundamental root cause we mean that no matter how effectively other constraints are remedied, per capita food production in Africa will continue to decrease unless soil fertility depletion is effectively addressed" (Sanchez et al. (2000). This narrowing down of fundamental root causes for declining food production to soil fertility depletion without regard to other factors, interacting highly with soil fertility, was questioned by Scoones and Toulmin (1999). As pointed out by the authors, "… the choice of what to measure depends on identifying those *limiting factors* [italic by authors] that make a difference to yields". … "There are many possible soil parameters which can be measured, but it is essential to make choices given limited financial and human resources for analysis" (Scoones and Toulmin 1999, p.40).

Nutrient depleted soils are inextricably associated with a wide range of other biotic constraints that can usually not be solved by improving the fertility status of the soil. Multivariate on-farm trials on nutrient stressed soils often reveal that the most yield-limiting factor is not soil fertility but weeds (Carsky et al. 1998, Nolte et al. 2001) and pests (Weber et al. 1996). Yield limitation due to poor soil fertility is often hidden and becomes only important when the other problems are solved. One of the most often quoted examples for a dominant weed constraint is *Striga*, a parasitic weed attacking cereals in the savannah zones of SSA (Weber et al. 1995, Mekuria and Waddington 2002). Huge gaps exist in our knowledge of how crop yield loss on degraded soils relate to other soil-borne pests and diseases. Further, stressed plants are more vulnerable to attack by non-soil-borne pests and diseases – see for example, Schulthess et al. (1997) for cassava, and Schulthess et al. (1999) for maize in the humid zone of West And Central Africa. As yet researched are only few interactions between soil-borne pests and beneficials – belowground biodiversity at large (Sikora et al. 1994, Vilich et al 1997). Microorganisms that have definite root-health-promoting effects have been identified: vesicular-arbuscular mycorrhizae (Sikora 1995), rhizobacteria (Guo et al. 1998), fungal pathogens or parasites, and more recently mutualistic endophytes (Sikora et al. 2000). Such biological control agents (Lohmann and Sikora 1989) can be applied to seed, transplants or plantlets from tissue culture before the host is planted into infested fields to ensure targeted placement, higher levels of activity, reduced production costs, simplified formulation and application (Racke and Sikora 1992), reduced extension costs, and minimal impact on the environment. Furthermore, farmers' perceptions of soil pests are usually very poor – because they are mostly invisible to the human eye – requiring intensive training (van de Fliert and Braun 1999). Consequently, farmers note declining productivity, but attribute this to poor soil fertility, whereas the real cause may very likely be soil-borne pests. Even researchers often confound signs of chlorosis and nutrient deficiency of suppressed, stunted crops with root damage by soil pests. Providing additional fertilizer, therefore, under such circumstances, is not a solution, but misguided waste, as damaged root systems are unable to make efficient use of the available nutrients. A combination of interventions, synergistic in effect, is often the solution to such problems (Sikora et al. 1989, Hauser 2000).

6. Nutrient management beyond N-P-K is required – and is N from BNF cheap for farmers in SSA?

Many papers discussing soil fertility problems in SSA mention only N and P (see for example, Sanchez et al. 1997,), and occasionally K (Stoorvogel and Smaling 1990). Even the CP-SSA pre-proposal lists only of N and P as nutrient constraints, besides low soil organic matter (SOM). It is the nexus between soil degradation and unsustainable SOM management (Rees et al. 2000, Martius et al. 2001) that determines this analysis, because N and P capital in the soil is mainly in its organic matter (Giller et al. 1997, Buresh et al. 1997). In terms of nutrient management, such an approach is far too narrow – besides the fact, that sulfur capital is also mainly to be found in SOM (Coleman et al. 1989). Although, N-P-K availability is often limiting in SSA soils, there are many situations when N-P-K fertilizer application did not increase crop yield. For example, Schultz et al. (2003) found that only a cocktail of Ca-Mg-S-P in combination with N fertilizer was able to increase maize yield from 2 Mg ha^{-1} to 5 Mg ha^{-1} on severely degraded soils in the northern Guinea savanna of Nigeria. Sulfur (Menzies and Gillmann 1997) and zinc (Howeler 1981) may limit cassava yields on acid humid zone soils. Calcium deficiency on acid soils leads to 'pops', empty pods of groundnut (Smyth and Cravo 1992, Wendt 2002, Wendt and Fonjak, submitted), a major crop in the humid zone of West and Central Africa. Zinc may limit maize yields on sandier dry-savannah soils as found by Wendt and Rijpma (1997) in Malawi and Agbenin (2003) in Northern Nigeria. Molybdenum and copper deficiency was found to limit N-fixation and growth of *Phaseolus vulgaris* in Tanzania, Malawi, and Zambia (Brodrick et al. 1995).

Nitrogen deficiency is the most widespread nutrient management problem in SSA's soils for N-demanding crops, such as maize. There has been an overwhelming investment in legume research, trying to utilize biological N-Fixation (BNF) for smallholder farmers. But is this the cheap form of N-input for farmers under their current circumstances, as pointed out in numerous publications? Farmers' do not use mineral fertilizer, because they cannot afford it, they lack liquidity, or find it a risky investment (Wyatt 2002). This notion of cheap N-input via BNF is proving increasingly wrong under current farmer circumstances, notably with soil-improving legumes, such as N-fixing trees, shrubs, and herbaceous legumes. What is often not taken into account are establishment and maintenance costs of planted fallows. Gockowski et al. (2000) determined on 18 farms in 6 villages of southern Cameroon, that the estimates for labor time to clear Calliandra plots did not vary significantly from the labor effort to clear natural fallow, dominated by *Chromolaena odorata*. However the amount of Calliandra biomass had a significant positive effect on the amount of labor clearing effort, as expected from a tree with relatively hard wood, in contrast to the shrubby natural fallow biomass. This result indicates that whether there is 5 Mg ha^{-1} of Chromolaena-dominated fallow biomass or 10 Mg ha^{-1} does not make a difference, but more Calliandra biomass requires more labor input. Hauser (1999) determined in an on-station trial that Calliandra tree fallows require twice as much labour for slashing than Pueraria and Chromolaena fallows, with no difference between the latter two. Burning, commonly practiced by farmers, required 8 times more labour for the tree fallow than for the two other fallow types, because of the high amount of wood. However, the total time required for slashing, burning, cleaning, and preparing the land for groundnut-cassava-maize cropping did not differ between the fallow types. Yet, this will be different without the groundnut, because fields do not have to be cleaned for planting cassava-maize to the same extent as for groundnuts, so labour savings after tree fallows, caused by suppression of Chromolaena stumps in the fallow phase, do not matter as much.

At least two intensive clean weedings are required to establish planted fallows with small-seeded erect herbaceous legumes, such as *Stylosanthes guianensis*, *Crotalaria juncea, Chamaecrista rotundifolia,* or *Aschynomene histrix* in the humid zone of southern Cameroon (Assengue 2001). Few farmers are willing or able to do this, because even major staple and cash crops such as cassava and maize (Nolte et al. 2001) do not get weeded sufficiently and in time. Publications on this subject are scarce – see for example, Tarawali and Mohamed-Saleem (1994). This forced Elbasha et al. (1999) to use a flat cost rate of $150 ha^{-1} for establishing fodder banks across all 15 countries investigated. Publications testing the N-effect of these legumes (mainly on maize) rarely mention establishment or maintenance costs of their trial fields. Many on-farm legume trials have been planted by researchers and their technicians, see for example Douthwaite et al. (in press).

The focus of legume integration into cropping systems should be changed to cash, food and feed generation – Mucuna seeds for pigs (Flores et al. 2002), management of noxious weeds – Mucuna against imperata (Chikoye and Ekeleme 2000), combating soil-borne pests – *Aschynomene histrix* against yam nematodes – , and reducing diseases – Mucuna against nematodes (Nogueira et al. 1996). Weber (1996) provided a review of the challenges for research and development for the savannah zone of West Africa, and a list of such legume characteristics is available in the LEXSYS database (ftp://ftp.bangor.ac.uk/pub/departments/af/LEXSYS/). Further, a decision support tool for integration of some legumes into cropping systems (LEGINC) has recently been developed in the forest-savannah transition zone of Ghana and a demonstration version is available at ftp://ftp.bangor.ac.uk/pub/departments/af/LEGINC/.

Grain legumes, such as soybean and cowpea, offer cash income and food in addition to other services, such as N-input. Their integration into cropping systems should be pursued first, despite much smaller effects on soil conservation. Correct choice of germplasm (Sanginga et al. 2002) can decrease soil degradation, increase yields, and promote suicidal *Striga* generation, thus improving the subsequent maize crop. Some dual-purpose germplasm with low harvest N-indices has been developed for NRM purposes but this requires more attention by legume breeders (Snapp et al. 1998, Schultz et al. 2000) so that farmers realize adequate grain legume yield while cycling nutrients and bringing nitrogen into the system through BNF. In areas with high population densities, such as Northern Nigeria or Southern Benin, land is so scarce that farmers are not willing to sacrifice a crop for a fallow (Manyong et al. 2001), even if its improved (Douthwaite et al. in press). A similar farmer response was reported from the Machakos district in Kenya (Freeman and Coe 2002). These situations provide an incentive to adopt germplasm that produces a marketable crop while improving soil fertility.

Claims of large-scale adoption of improved fallow technologies in SSA (Sanchez, 1999) are overly optimistic, at least in the West and Central African context. Adoption of improved fallows occurs in spots on the West and Central African map, but is extremely low compared to the number of farmers facing soil degradation problems. In Rwanda, where soil degradation is very severe, a review revealed basically no adoption of improved fallow technologies (Drechsel, 1996). 'Adoption' seemed to be wrongly assessed at first in the case of Mucuna in southern Benin where 100,000 farmers were reported to use the technology (Versteeg et al. 1998), but then many refrained from it, because Sasakawa 2000, an NGO, purchasing Mucuna seeds for large-scale distribution, stopped their activities (Douthwaite et al., in press). Exactly the same was experienced in Mali with *Dolichos lablab* (Kelly et al. 2002). Farmer-to-farmer diffusion has only been very limited for the alley cropping technology in Benin and Nigeria (Douthwaite et al., in press), leaving doubts that 'adoption' of the technology (Adesina et al. 1999, Adesina and Chianu 2002) has really taken place. A multitude of socio-economic constraints to adoption are often cited, notably for tree-based fallows (Dvorak 1996, Franzel et al. 2001). Even effects on crop yields in West and Central Africa are often disappointing. Vanlauwe et al. (2001) reviewed literature, revealing that at most 140% yield increase with maize can be achieved in West Africa with planted fallows vs. an unfertilised control – starting from a yield level of 1 Mg ha^{-1}. Hauser et al. (2002), reviewing most publications on tree fallows in West Africa, found in only 20% of the experiments a positive response of crop (mostly maize) yield to tree fallow vs. 25% showing actually yield reductions, the remainder having had no significant effect. These experiences led IITA to stop most experiments with tree fallows for the time being, creating time for re-thinking the approach.

However, niches do exist for tree-based fallows in this region and they should be pursued. An example is *Acacia auriculiformis* woodlots for fuelwood production and soil fertility management in southern Benin (Versteeg et al. 1998, Douthwaite et al 2001, unpublished). The old concept of selecting and integrating multi-purpose trees should be turned around: focus first on the by-product and then on the soil fertility effect. Such woodlots, however, have to be probably fertilized with nutrients other than N in order to replenish nutrients exported with the wood (Nolte et al. in press), because sub-soil nutrient uptake of the trees, if any, is likely too low. Another example is the use of trees for recovery of 'comatose' soils, soils that are so degraded that farmers have given up crop production on these lands (Kang et al 1997, Tian et al. 2000). Examples are mid-slope positions in inland valleys, which often have lost parts or all of their top soil to erosion, exposing plinthites or *carapaces* at spots (Raunet 1985).

The adoption potential for planted woody fallows in Eastern and Southern Africa seems different. Kwesiga et al. (1999), Place et al. (2002), and Franzel et al. (2002) reported high adoption rates of Sesbania tree fallows and several woody fallows, such Crotalaria, Tephrosia, and Cajanus in Zambia and Zimbabwe. However, Snapp et al. (2002) pointed out that in densely populated areas, such as Malawi, farmers are as reluctant as in Northern Nigeria to forgo maize production for legumes, although the latter were highly productive.

To conclude this section, planted fallows are an option for areas where farmers still have enough land to set aside for fallowing and enough labour, or liquidity to hire labour. However, many rich farmers in Zambia prefer less labour-demanding and therefore less costly fertilizer to planting Sesbania trees (Keil, 2001). Much more detailed research examining labour requirements of specific species is required, before embarking on a large-scale recommendation program. It appears that for planted fallows, herbaceous (e.g., Mucuna, *Crotalaria juncea*) and shrub legumes (e.g., Cajanus, Tephrosia, *Crotalaria grahamiana*) have higher chances of adoption than trees, at least in most of West and Central Africa, because they require less labour for management than trees and do not rely on secured land tenure. Despite much lower chances of adoption than for dual-purpose grain legumes, continuation of well-targeted research work on non-grain legumes, particularly spreading herbaceous species, is warranted, because the latter have much higher potential to conserve the soil and generate organic matter. However, if soil organic matter can sustainably be increased through these technologies remains to be clarified (Vine 1953, Merckx et al. 2001, Diels et al. 2002).

7. Mechanization to increase chances of large-scale adoption of soil-improving legumes

The labour constraints inherent in using legumes for soil conservation can only be overcome by mechanization. It is noteworthy, that this notion is completely lacking in most publications calling for improved NRM practices (Sanchez et al. 1997, Sanchez et al. 2000, Izac and Sanchez 2001, Sayer and Campbell 2001, or see the whole book edited by Barrett et al. 2002). Rarely, is it mentioned (Steiner 1998, Steiner 2001). Impressive technologies (e.g., conservation tillage) and machines for smallholders (Florentín et al 2001, de Freitas, 2000) have been developed – often by farmers – in other developing countries (e.g., Latin America, Asia) and they should be tested in farms of SSA. Adopting NRM practices is an investment choice (Barrett et al. 2002a) as is mechanization. "… why has the process of mechanization been so slow and why is the hand hoe so tenacious in Sub-Saharan Africa? Why has the spread of mechanization in Sub-Saharan Africa been slower than in countries such as India, Pakistan, and China, where labor is abundant and wages are low?" Yet, "solutions generated by African farmers for increasing food production from a given area of land have been strikingly similar to the solutions found historically in other parts of the developed or developing world." (Pingali et al. 1987). "The most successful experiences in the developing world, such as the mechanization of milling, pumping, or harvest processing, did not depend on special interventions either. Once economic conditions have led to an effective demand for machinery, private firms in the developed world have responded rapidly. Private initiative has been the dominant force in the generation of mechanical innovations and the development of an agricultural machinery industry. The primary short-run constraints are: (i) the availability of credit; (ii) training programs for animals and farmers; and (iii) blacksmith training" (Pingali et al. 1987). Thus, in terms of subsidies and necessary credit schemes, constraints are similar to adopting NRM practices and similar solutions can be envisaged for mechanization. However, as de A. Machado et al. (2001) point out for large-scale adoption of the no-tillage technology in southern Brazil, a close collaboration between governmental institutions (research centers and extension service) and farmer associations, agrichemical companies, seed companies and agricultural machinery companies was crucial. First steps to set up such a network have been initiated (http://www.fao.org/act-network/). Much process-type research on no-tillage systems has been done in the past (Akobundu and Deutsch 1983, Lal 1995b, Derpsch 2001), but testing and adaptation of technologies in SSA is what is missing and this CP should get involved.

Ndlovu and Mugabe (2002) also mentioned mechanization as an option to pursue in order to achieve adoption for improved crop-livestock management practices, such as fodder banks.

8. Crop-livestock integration

Increased demand for agricultural produce of both, crop and animal origin, results in huge pressure on the farmers' land resources. Responding to such demand, farmers plant crops on every available piece of land, and they plant every year, meaning fallow periods have disappeared. This also means that fallow and marginal land for livestock grazing are considerably reduced, and both the food (for family and for income) and the feed for livestock have to come from the same piece of land (Smith et al. 1997). Whilst this could be a disastrous situation with respect to natural resources, it also presents opportunities to maximise the synergies between crop and livestock production. These include improving the quantity and quality of crop stover (especially grain legumes and cereals), maximising the benefit of improved feed in terms of livestock performance and manure production, ensuring optimal nutrient capture and return to cropland (Tarawali et al. 2001). In some niches the use of non-grain herbaceous legumes, usually with multiple benefits (e.g. soil fertility, pest reduction as well as fodder) also offers an appropriate option (Tarawali et al. 1999; Sumberg 2002). Elbasha et al. (1999) found some impact of that research in SSA, but the numbers of adopters are rather small. They looked at data from 15 countries and found a total of 27,000 adopters. The research investment turned out to be profitable, but large-scale adoption is certainly missing, indicating that the investment in establishing fodder banks is less profitable for most farmers under current circumstances. Labour demands for establishment, maintenance, cutting and carrying are too high at present (Ndlovu and Mugabe 2002).

For many farmers in the dry savannas such crop-livestock integration is already a way of life, and becoming so for more with increased settlement of formerly nomadic pastoralists (Jabbar 1992) and settled crop farmers investing in livestock enterprises (Okike et al. 2001). Planting crops and using mangement practices to ensure both grain and fodder are produced, as well as returning the manure to the fields are common practices for such farmers. Our challenge is to enhance the productivity of such systems without degrading the natural resource base.

An example of crop-livestock integration, of interest to farmers in the humid zone of Cameroon, is the maize-soybean-chicken system. This system is increasingly used by farmers in peri-urban areas (Endom 2002). Their objective is to self-produce the main ingredients of otherwise purchased chicken feedstuff. Production costs can be reduced by 10-30%, depending on the variable market prices of maize and soybean, and crop yields. The chicken manure is used to fertilize maize and soybean or even better, to fertilize the more valuable leafy vegetables or tomatoes. An important researchable issue in this system (apart from integrated crop management) is to develop an evaluation system for the quality (protein and digestible energy content) of maize and soybean after each harvest, which can be used by farmers. This is important, because it determines how much of the other, purchased ingredients are required to compose the right feedstuff.

9. Scaling out and up of the interventions

Widespread adoption of NRM innovations requires cost-effective mechanisms for extending these technologies to large numbers of farmers. For greatest cost effectiveness, the farmers exposed should be the subset with the highest likelihood for adoption. These are the farmers who reinvest their on- or off-farm income into agriculture and who are conscious experimenters. Since NRM practices are knowledge-intensive, education levels are important. For example, Kelly et al. (2002) experienced that young, well-educated farmers were selected by their elderly peers to run a farmer training program. There are numerous factors, which affect the likelihood of adoption of a given innovation. They include inter alia policies and institutions, biophysical factors, organizational capacities for extension, infrastructure and market development, and household endowments of land, labour, and natural capital. Developing a clear understanding of how these elements interact and impinge on adoption is a crucial research objective for achieving the development goals of this CP.

Recognizing the local nature of most NRM issues and placing them in their broader livelihood context implies a process of achieving impact and adoption of new techniques through skills development of farmers. The first step in the process is to conduct a participatory planning and analysis to identify the set of issues and interventions that farmers want to try. Once processes of farmer learning and experimentation are established, scaling out of successful technologies happens through farmer-to-farmer diffusion. However, there is evidence that knowledge-intensive technologies experience less of such diffusion, because they demand intensive training (de Fliert and Braun 1999).

Soil-fertility policies should emphasis the development by private enterprise of bulk blending facilities (Vlek, 1996) for the production of compound fertilizers, which are tailored to the needs of specific crops (e.g., root and tuber crops). It is unlikely that a single intervention is capable of adequately addressing the issue of soil fertility. Instead a combination of interventions should be considered.

Large-scale adoption of NRM technologies, however, requires more. Effective market information as provided by the Rural Sector Enhancement Program (RUSEP) (http://www.usaid.gov/regions/afr/ss02/nigeria8.html ; http://www.winrock.org/fact/facts.cfm?CC=5341 ; http://cbdd.wsu.edu/networks/) or FOODNET (http://www.foodnet.cgiar.org/market/market.htm) and micro-credit schemes linked to commodity marketing, are powerful tools to enable wide-spread use of fertilizer (Dudal, 2002) and other NRM practices. Institutional reforms (e.g., extension services) should provide the right framework for adoption (Brader, 2002). Centralized government-funded extension services in most countries of SSA are more or less defunct, because they do not get the financial means to operate. Decentralizing them as in Northern Nigeria or even privatising them as in Côte d'Ivoire might improve their functioning. A participatory extension approach has been successfully implemented by Hagmann et al (1998) in Zimbabwe. However, recent political instability in Zimbabwe might have set back these achievements.

Intuitive information management can greatly enhance the scaling out of those NRM practices that have been 'constructed', tested and adopted in project areas. The use of farmer-accessible media, such as the radio (Foodnet 2002), is very successful in Uganda for spreading knowledge on markets and post-harvest opportunities and techniques. Many farmer communities, especially those near to major urban centers, have already excellent market information, but were so far constrained by rapidly spreading the news between members (Nicolas Bricas, pers. communication). Access to mobile phones has tremendously changed this, but phone networks are still insufficient, the more so the further farmers are away from cities. Therefore, supporting the build-up of these networks should be a good investment. This kind of knowledge transfer empowers communities to become professional market-oriented farmers.

Another important aspect is that visualisation of problems and solutions becomes vitally important in facilitating a shared perspective on problems and helps to develop decision-making capacity to deal with it (Röling 1994). Affordable new media, such as digital video cameras, can greatly help in this process – see for example recent work of CGIAR/sp-IPM (2002) on integrated *Striga* management in Africa and IITA/ASB (2002) on sustaining welfare and farming in the forest margins of the Congo Basin. Multimedia databases on CD-ROM can be used to visualize integrated pest management strategies for national researchers and extension agents (IITA/DFID (2002).

10. Strategy for areas with limited market access

Farmers living in areas with only limited access to markets (i.e., rural markets), who have problems in commercializing their crops are much less likely to adopt NRM practices. However, land-abundant have to be distinguished from land-scarce areas, because population density is another major driving force for agricultural intensification (Boserup 1965).

In a project area of Madagascar with land availability, Freudenberger and Freudenberger (2002) promoted initially agricultural intensification and rural income diversification through conservation enterprises, incl. eco-tourism, in order to deflect farmers from deforestation. Their efforts were very much focused on finding effective ways to extend techniques for agricultural intensification. However, after several years they realized that the impact of infrastructure, the train in their project, "dwarfs by far the potential impact of the programme's agricultural extension efforts". This example is typical for remote areas in the forest margins of SSA. High value non-perishable commodities are likely to be more profitable in such settings and should be targeted. These include export commodities, such as cocoa and coffee, and some non-timber forest products with high value in local markets such as *Ricinondendron heudelotti* in Cameroon and Gabon. For households in areas of land abundance, relative to labour, adoption of new innovations must be measured in terms of their returns to labour (Binswanger 1986). Introduction of improved germplasm of staple and new crops, adapted to soil stress and pest/disease resistant, have a high chance of adoption in these areas and should be pursued.

In land-scarce areas with high population density, though, farmers may adopt NRM practices, despite limited access to major markets. This was investigated by Barbier et al. (2002) and is documented by Seignobos and Yiébi-Mandjek (2000) for dry-season sorghum ('Muskwari') cultivation in Northern Cameroon. Farmers on their own restored degraded land and improved marginal land in adopting more intensive techniques and new crops. The diffusion of these indigenous innovations was achieved simultaneously with new social arrangements between farmers and herders. Both, technological and institutional interventions came about independently from any external assistance, neither by government agencies nor NGO's. Since they concurred with farmers' expectations, large-scale adoption was achieved.

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