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The economics of selected resource protection measures from the sub-humid to the arid regions of Benin-West Africa

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Abstract
In an ecologically, economically and socially highly diversified country such as Benin, very high effort in adaptive research is necessary to develop adapted technologies. This issue is demonstrated in the light of experiences of the PGTRN (Programme de Gestion des Terroirs et des Ressources Naturelles) in promoting sustainable agricultural practices in six agro-ecological zones all over the country.
The paper presents economic analysis for the most successful of these activities. The influences of key variables such as prevailing crop rotations and opportunities for their intensification, crop and wood yields and prices, opportunity costs for labour or availability of bush/fallow land on innovation profitability are quantified in their effect on level and variability of profitability.
As expected, the results show a highly site and situation specific profitability of the innovations, and therefore a high need for specific technology adoption and promotion. But such research is costly and difficult and therefore carried out only partially. Some of the reasons are inherent to the characteristics of resource conservation technologies in agriculture: long periods before the technologies can develop their full (positive and negative) potentials, long lags between costs and benefits; the partial subsidisation biases farmers' private cost-benefit-calculation.
However, there are also institutional hindrances: In this paper it is argued that it is improbable that any of the institutions actually involved in this area can carry out successful adaptive research in an isolated manner. Each of them, and the individuals within them, have certain limitations and vested interests which make them quite ineffective in developing appropriate technologies. Consequences resulting from these handicaps are discussed.
The study is based on a two month consultancy for the PGTRN. The data gathering methodology for the analysis is based on a mixture of participatory evaluation, farmer expert interviews and literature review.

Introduction
Benin is a small country in terms of area and population, but it has many agro-ecological zones. The existing farming and, more generally, rural livelihood systems, are extremely divers in their external determinants and internal objectives between subsistence and market orientation. The diversity of farmers' situations is further enhanced by many local socio-political and market-related constellations. Often, technological and institutional innovations have to be fine-tuned if they are to be adopted by rural populations. The complexity makes it extremely difficult and costly for agricultural research and extension to develop appropriate technologies.
In this paper it is argued that this fine-tuning, which in reality is often a highly complex and

labour-intense issue, is beyond the individual capacities of the organizations actually involved in agricultural research and extension, which basically are the National Agricultural Research Institute (INRAB), the national (UNB) and several foreign agricultural universities, the regional extension offices (CARDERs) which were strongly down-sized during past structural adjustment programmes, and an ever-growing number of local Non-Government Organisations (NGOs). Each of these institutions, and the individuals within them, have certain limitations and vested interests which make them quite ineffective in conducting useful adaptive research.

This issue is demonstrated in the light of experiences of the PGTRN (Programme de Gestion des Terroirs et des Ressources Naturelles), a German/French co-sponsored resource protection project which works in six agro-ecological zones all over the country. At each site, a local NGO is responsible for executing participatory land use planning. Thereafter, one of their tasks is to assist villagers in selecting among a range of resource protecting activities such as alley cropping, community and individual tree plantations, contour ploughing and construction of earth dams, bee keeping, agro-forestry etc. These activities are partially subsidised by the project but basically executed by farmers. Subsidisation is a heavily disputed issue, it varies between 0% and 100% according to the individual or communitarian character, the assumed ecological benefits, the costs of establishment, the number of years of collaboration with a village, etc. In an earlier phase, INRAB teams were directly sponsored to develop appropriate technologies, but presently technology development is rudimentary.

Methodology

The study is based on a three month consultancy of a national and an international consultant. The technologies to be analysed were chosen by PGTRN and the executing NGOs, basically according to the two criteria " most demanded by farmers" and "most promising". They are: slope-parallel anti-erosion walls (AEW) combined with contour ridging, with or without vegetation in the form of Vetiver grass or leguminous trees; soil fertility restitution (SFR) via integration of Mucuna (a cover leguminous crop) or Acacia auriculiformis (a leguminous tree) into crop rotations; individual forestry with Acacia auriculiformis, Eucalyptus or a tree mix; bee-keeping and communitarian forestry for gallery forest protection. Not all technologies are carried out or analysed for all sites, only the two most important were selected per site.

Data collection prior to the consultancy was rudimentary, the consultants had about one week per site. Thus, most of the data is based on semi-formal interviews with non-randomly selected farmers, triangulation of information and the use of secondary data where available. The lack of secondary data and formal analysis in general was quite surprising because the chosen technologies are promoted by a large number of organisations for a decade or more.

The basic assumption was that all the proposed technologies have the character of an investment in which initial inputs have to be remunerated by a stream of future production which in most cases are a combination of yield improvements of complex crop rotations as well as "side products" such as fuel and construction wood. In some instances the resource conservation measures engender further crop production improvements such as higher fertiliser use due to lower risk of fertiliser loss, in other instances there are none such side-effects.

We systematically took into account that the resources used are not for free: the improved crop rotations compete with existing ones on the employed land or, in certain instances, with fallow land (reference situation); the labour force used can create income in alternative activities; and the capital invested (and income foregone) has to be compared with alternative uses for investment or consumption. In consequence, opportunity costs (OC) for resource use were determined: for land, the gross margins of the reference situation which was either the typical crop rotation or its average per year in case that a technology such as AEW established on a larger field does not affect a crop rotation in chronological order but several crops on

small plots simultaneously; for labour, three alternatives were calculated which would represented typical farm households situations: no opportunity costs for increased labour input, labour costs according to hired labour wages, and labour costs weighted by a monthly index representing relative scarcity of labour according to a labour scarcity calendar which was established with small groups of farmers.
The annual differential of new technology gross margin minus reference situation gross margin minus labour costs was calculated for a period of time specific for each technology (between 4 and 15 years), which served to calculate discounted net benefit increase (NBI) and, where possible, internal rates of return (IRR) per hectare. Comparing typical investment situations and local credit conditions, it can be assumed that the opportunity costs of capital are at least 40% per year for small farmers. This value was, thus, set to be the minimum required discounting rate (DR) for which NBI should be larger than zero and which IRR should outset.
In sight of the weak data base and the many assumptions for land and labour conditions of typical farm household situations, extensive use was made of sensitivity and risk calculations in which the impact of changes in yields, prices and labour costs on the NBI (in general at 40% adjustment rate) was tested. Whereas in sensitivity analysis the impact of discrete variations of key variables on the result can be checked and compared, risk models which used Monte-Carlo-Simulation can handle simultaneous changes of many variables and calculate the distribution of probabilities of results, for instance the probability of an income loss.

Results

In this short article only an overview of findings can be presented (Table 1). The results have been converted into signs according to the following key:

	Thresholds and corresponding signs in Table 1			
NBI (average FCFA/year)	>20.000 +++	10-20.000 ++	0-10.000 +	<0 -
Sensitivity of NBI to changes in yields (% before NBI changes sign)	>50% ---	10-50% --	0-10% -	
Sensitivity of NBI to changes in establish-ment costs (% before NBI changes sign)	>40% ---	10-40% --	0-10% -	
Sensitivity of NBI to changes in OC of labour (% before NBI changes sign)	>20% ---	10-20% --	0-10% -	<0% +
Risk of loss	>20% ---	10-20% --	1-10% -	0% +

n.a.= non applicable

What appears is a very heterogeneous level and stability of profitability of the analysed technologies according to site. For instance, anti-erosion measures vary from high to low profitable, soil fertility restitution from medium to low (at other sites they are even less convincing). Forestry does not meet the high performance of 40% rate of return to investment, but at several sites it is near to this. It must be highlighted that forestry is particularly sensitive to location due to the high transport costs of wood.
Also the sources of risk and the degree of sensitivity to important factors influencing profitability calculation are not homogeneous. Sometimes reactions of crop yields dominate, sometimes the opportunity costs of labour, in forestry and beekeeping investment costs often (but not always) constitute the most important factor.

Table 1 Synopsis of findings on profitability of resource protection measures analysed

Measure and site	Calculation period (years)	NBI (at 40% DR)	Sensitivity of NBI			Risk of loss (risk simulation)	Variables at risk	Remarks
			Yields -20%	Establishment costs +20%	OC of labour +40%			
Soil fertility restitution								
Allada (Mucuna)	5	**+**	**--**	n.a.	**+**	**-**	maize> groundnuts	Loss of land in 2. season, lack of market for Mucuna grains, combination with mineral fertiliser recommended
Aplahoué (Mucuna)	5	**++**	**--**	n.a.	**+**	**-**	maize>cow-pea, manioc	Loss of land in 2. season, lack of market for Mucuna grains, combination with mineral fertiliser recommended
Anti-erosion measures (slope-parallel walls with or without vegetation)								
Aplahoué	5	**+++**	**--**	**-**	**-**	**-**	cotton> maize, cowpea	Well adapted to local conditions, mainly women benefit
Ouessè	4	**++**	**---**	**-**	**--**	**--**	cotton> maize, ground-nut	Cashew nut tree could be an option to stabilise AEW, adoption after fallow seems to be wide-spread
Ouaké	11	**+**	**---**	**-**	**--**	**-**	yams> cotton, maize	Few steep slopes in the region, Cashew nut tree could be an option to stabilise AEW
Boukoumbé	5	**++**	**-**	**-**	**-**	**+**	groundnut, maize, OC of labour	Vétiver grass ok, particularly interesting if combined with intensifica-tion (cash crops and mineral fertiliser)
Forestry								
Allada (Acacia on fallow)	14	**-**	**0**	**--**	**-**	n.a.	yield and price of wood	IRR about 10-15%, particularly interes-ting with good market access for wood, and if fallow available, for large farms
Ouessè (beekeeping in galerie forest)	14	**-**	**--**	**---**	n.a.	n.a.		IRR about 30%, forest protection requires additional measures, including other types of forest use
Ouaké (Eucalyptus on crop land)	14	**-**	**-**	**-**	**-**	n.a.	yams, cotton, maize, wood (stems)	IRR about 5-10%, interesting for self-consumption or if good market access and fallow available, for large farms
Boukoumbé (Acacia and Euca-lyptus on fallow)	14	**-**	**--**	**-**	-9%	n.a.	wood (stems)> OC of labour	IRR about 30%, interesting for self-consumption if farm is far away from provision areas, advantages women

But even within sites, there are pronounced differences in the economic performance of technologies according to

- natural resource properties (soil properties, inclination, erosion and sedimentation patterns),
- farm household system (degree of crop-livestock integration, man-land-ratio, opportunity costs of land, labour and capital which are often particularly influenced by off-farm employment opportunities),
- cropping systems (including influence of ethnic group on cultivation and transformation know-how and subsistence consumption pattern, type and intensity of existing crops and rotations and possibility to intensify cropping systems after establishment of improved resource technologies, particularly the intensity of organic and mineral fertilizer use and potential),
- location of farms with respect to market and local distribution of resources (particularly for wood),
- resource ownership (often it is forbidden for non-owners to plant trees, certain crop residues are difficult to protect against divagating animals),
- division of labour (influenced by ethnic group, off-farm opportunities, etc.)

Two examples may illustrate these somehow abstract categories, anti-erosion walls and forestry on sites in the Province of Atacora:

A) Anti-erosion walls: In Boukoumbé, a densely populated arid area of the North-West Atacora province, anti-erosion walls seems to be well appreciated in areas with steep slopes, although the establishment is rather burdening in terms of labour on the stony hard shallow soils. Vetiver grass is accepted, not so much for its fodder procurement or particle filter characteristics but for stabilising walls. The negative influence of the grass on neigbouring crops (competition for water, space, light, nutrients) is reduced by systematic burning in the dry season which weakens the weed to a maximum. The reduction of erosion animates farmers to increase the share of cash crops in the rotation, particularly maize and some cotton, and to increase organic and inorganic fertilizer use. This is probably the most important effect of the technology. In contrast, Acacia seems to be unappropriate, the fertilizing effect of litter is less important than the competition with crops, and the maintenance of trees is less easy to organise than of Vetiver.

In Ouessé, a land-abundant immigrantion sub-humid zone some 300 km South-East of Boukoumbé, the erodability of the deep light soils is also very remarkable. But farmers are reluctant to establish AEW on old fields because this requires them to change the direction of the ridges, a work that is mainly done by hired labourers who demand some additional money to do so. In contrast, on freshly cultivated fallow land it seems that the slope-parallel ridging is accepted, but not with the recommended accurate technology which requires some labour input of experienced workers and a special instrument (a water level in form of an “A”) but with a more crude and more robust adaptation. Local farmers would prefer to let the old fields fall fallow and establish AEW with a new cultivation cycle. But there are some more aspects which are taken into consideration: I) the cropping systems preferred by Nago (a Yorouba tribe) farmers is based on manioc, that of Mahi (a Fon tribe) farmers on maize. Both systems offer different threats and opportunities with respect to erosion and erosion control. II) On homestead-near plots, increasingly cotton is grown for which mineral fertilizer is available on credit and which permits thereby to crop longer periods on the same field – this avoids burdensome fallow clearing and long travel costs to reach new fields. III) In addition, immigrant hired labourers gain right to obtain some land after a few years immigration – they are

often given the old fields in order to avoid their installation of fresh fallow which would give them more permanent land rights and hampers their control. For this purpose, a technology stabilizing cropping systems is welcome. Wood, however, is so abundant in the region that its cultivation is not interesting, wherever former projects have insisted in planting forestry trees on the AEW they are cut down after a few years. In contrast, trees with other direct uses (Cashew nuts, Mangos, etc.) are highly appreciated, for their additional income while permitting to mark the land ownership.
B) Forestry: In Bouboumbé, the promotion of tree planting is of limited success. The homesteads of the dominating tribe, the Bètamaribè, are scattered over the landscape without settlements, thus there are less densely exploited areas around villages. Eucalyptus, the forestry species most adapted to the rough climate, is not very useful for the type of building preferred by the local people ("Tata Somba") for which long-lasting wood is searched without need of the special form. In addition, widespread Baobab trees are not felt due to nutrition and religious reasons, and many families protect woody vegetation under the Baobabs for firewood.
In Ouaké, some 100 km South-East with a little more humid climate and slightly less densely populated, Eucalyptus for home-consumption is highly appreciated. The building here is the standard grass or zinc-roofed rectangular house with slight roof inclination, for which Eucalyptus provides excellent material due to the straight shape of secondary shoots. In contrast, for carpentry for which Eucalyptus was originally introduced, the wood is hardly marketable because of the low resistance and relatively easy availability of traditional carpenter wood in the sub-humid forests south of here. Acacia, which grows acceptably in the region, is not at all adapted because I does not provide good construction wood, and fuel wood is (still) not scarce enough to claim plantation.

Conclusions

In Benin, the diversity of natural, market, social, legal, ethnic and farm household situations makes it almost impossible to develop recommendations in the field of natural resource management which are valid for a large number of farmers. Most technologies must be adapted and fine-tuned to the extent that the extension phase of the classic innovation development process tends to disappears in favour of an extended adaptive research phase.
For this adaptive research, the existing institutions are not well prepared, and in addition strong personal and vested interests of staff and institutions as a whole make it improbable that any of them can carry out useful research in an isolated manner.
The research institutes, basically are the National Agricultural Research Institute (INRAB), the national (UNB) and several foreign agricultural universities, do not have the personal and financial capacities to execute research on such a large variety of locations and issues. Resource and (agro-)forestry technologies in particularly render adaptive research problematic: long periods before the technologies can develop their full (positive and negative) potentials make innovation evaluation unfeasible within medium-term projects; at the same time, long lags between costs and benefits make adaptive experimentation by farmers difficult and even unlikely if major cash inputs are required; the partial subsidisation which is necessary to overcome low short-term profitability biases farmers private cost-benefit-calculation.
In addition, experiences of PGTRN (and other development projects) in cooperation with researchers of various institutions insinuate that they are often not really interested in sharing experiences and knowledge. They can gain from monopolising their position, which in a small economy such as Benin in often almost unique, giving expertise away

in unusable small units, gaining consultancy revenues which they can not reach under any scientific gratification scheme.
NGOs and CARDERs (the latter were strongly down-sized during past structural adjustment programmes), on the other hand, may have strong interests in acquiring special knowledge and local leadership in technology diffusion. But particularly NGOs can not be supposed to have a natural interest in promoting the most farmer-profiting, self-diffusing innovations. In contrast, in their role as development brokers they run better with technologies which require brokerage, subsidies, active intervention. Subsidies for technology adoption (and other services allowing a grant or corruptive element) make these institutions indispensable as channels for donors, warrant them a dominant and useful position within the rural society, and allow them to "buy" participation in whatever programmes and activities which the population would not accept otherwise. There is, thus, reserve in the NGO community towards simple agricultural technology development (also because competence is not striking), and a preference towards technologies with at least some communitarian, social or environmental elements which promise social welfare benefits which, in turn, can justify continuous subsidies.
Regarding this constellation of capacities and interests, it seems that only combined efforts under donor (or good government) leadership can direct a user-centered, efficiency-targeted and locally adapted technology generation and adaptation process. The actors' roles - rights, gratifications, duties - must be carefully counterbalanced in order to assemble the virtues, weaknesses and interests of the different partners for maximum efficiency in developing appropriate technologies.
Researchers contribution should render NGO staff able to conduct simple research on their own. But it must also be used to warrant quality of key issues of this research such as site and participant selection. Research protocols should be adjusted to local needs and realities (crops, technology level) and not to researchers general research agenda. Data collection and elementary analysis must be carried out by NGOs, research can bother for compilation on a broader or more sophisticated level.
NGOs can bring in experiences with flexible participatory (technology) impact assessment (PIM), particularly useful for technologies which affect the whole farming systems and which develop the main impacts only several years after establishment. Due to long development periods, technology impacts must probably be evaluated on trials not established by the current project. The choice of reasonable control treatments is of summary importance and must be solved more flexible than in standard agricultural trials. However, if not well documented and controlled, such a PIM is easily manipulated for the NGOs' own purposes. In this domain, research can be useful as control instance and for guaranteeing some minimum quantifiable standards.
In the end, best guarantee for good adaptive research would be an active involvement and capacity building of normal farmers in participatory technology development, not those few privileged ones often found in practice. Simple test designs, protocols in local language, assistance in acquiring and using simple measurement instruments, and over all the development of the conviction that this research work is in their own immediate interest, would greatly enhance adaptive research.
The proposed structure would be a at least partial turning away from classic distinction between research and extension as a concession to the fact that homogeneous farming systems or recommendation domains are very small. However, this is a long and stony way, and donors must be willing to finance it instead of quick realisations which often, however, do not last very long.