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Soil Fertility Management in West African Land Use Systems
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Resource management research in semi-arid West Africa: Challenges and new opportunities*

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ABSTRACT

This paper reviews past themes and results of resource management research and the constraints to adoption It proposes future themes and approaches to increase resource management effectiveness The key themes for future research in resource management are reducing mineral fertilisation costs, increasing plant nutrient and water uptake, increasing the organic matter in the systems and exploring the possibilities for small-scale supplementary irrigation Multi-disciplinary approaches must play an increasing role as must new techniques in modelling and spatial analyses Exploiting the existing experimental databases will permit quicker progress at lower cost

Key words: Multi-disciplinary approaches, spatial analysis, modelling, market-oriented development

RESUME

Recherches sur la gestion des ressources dans la zone semi-aride d'Afrique de l'Ouest: Défis et nouvelles perspectives

Cet article propose des themes et des approches scientifiques pour des recherches dans le domaine de la gestion des ressources naturelles dans les zones semi-arides de l'Afrique de l'Ouest Les themes prioritaires sont la reduction des coûts de la fertilisation minérale, l'amélioration de l'efficacité dans l'utilisation des éléments nutritifs et de l'eau par les plantes, l accroissement des disponibilités en matière organique et la recherche des possibilités d'irrigation à petite échelle complémentaire A cela s'ajoute la mise en oeuvre d'approches pluridisciplinaires en utilisant des outils tels que la modélisation et les analyses spatiales Enfin, l'exploitation des résultats expérimentaux et des connaissances devraient permettre d'entreprendre assez rapidement les recherches envisagées et d'en réduire les coûts

Mots-clés: *Approche plurdisciplinaire, modélisation, spatialisation, développement orienté par rapport aux besoins du marché*

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INTRODUCTION

The West African semi-arid tropics, receiving an annual rainfall ranging from 400 to 1000 mm and having an average growing period of 60 to 150 days, cover a vast area from Senegal to Cameroon Although temperature and day length are favourable for plant growth and phytosanitary pressures are relatively low, rainfall is not only low but highly variable in space and time, and the soils are poor, deficient in major plant nutrients (especially phosphorus) and low in organic matter content Rainfed agriculture systems are based on the drought-resistant traditional coarse grains (millet and sorghum) and legumes (groundnut and cowpea), with introductions of maize and cotton in the better-watered areas (>800 mm) Cattle and small ruminants are kept predominantly in transhumant pastoral systems, but also in agro-pastoral systems Although numerous tree species form part of the agricultural landscape and are valued for various uses, the planting of perennials to construct what one might consider as 'intentional' agroforestry systems is rare

Agricultural productivity in the dryer parts of the zone stands out as having one of the most disappointing records to date With the exceptions of cotton-cereal systems, maize-based systems and several smaller projects with contract farmers, the use of inorganic fertilisers is virtually absent Although there are some places with high population density where traditional systems have evolved to maintain soil fertility levels without fallows through integration of livestock and intensive use of organic matter, in general farming systems are extensive in relation to the land, with fertility management through fallowing rather than active nutrient management The reduction of fallow accompanying the rapid growth of population is leading, in many places, to 'agricultural involution' (Boserup 1965), wherein soil mining is no longer paced at a rate which permits the natural regeneration of fertility, with the consequence of declining yields

The purpose of this paper is to consider the nature of the challenges posed by the low and declining productivity of this zone for future resource management (RM) research It starts by reviewing RM research results with emphasis on the crop and soil components, and the reasons for their limited adoption by farmers, which serves as a basis for identifying priority themes, approaches and methodology issues for future RM research The starting point of the analysis is the observation that the failure to raise productivity has occurred despite the availability of a considerable body of science-based techniques, proposed in the context of development projects for quite some time

PAST RESEARCH THEMES, METHODOLOGIES AND RESULTS

Resource management research in the region has its roots in the late colonial period, as part of productivity raising approaches It resulted in a range of high yielding packages combining improved varieties and recommendations on fertility enhancement (usually via complex inorganic fertilisers) and cultural practices (planting dates, spacing, weeding and crop rotations) Packages have been available for groundnuts since the early 1950s, for cotton since the 1960s and for cereals only since the late 1970s Over

time, several other lines of RM research have been introduced Inorganic soil amendments (liming, phosphorus) have been shown to have a multi-year impact on soil fertility, organic matter applications although frequently seen as a less costly substitute for the inorganic fertilisers, have been established to be their necessary complement in long-term fertility management Various 'rural engineering' techniques (hedgerows, bunds, tied ridges) have been designed to conserve the soil against wind and water-induced erosion and, in the very dry areas, to enhance water availability to crops Irrigation has mainly been considered on a large-scale capital-intensive basis

The extension of RM research has occurred in tandem with an evolution in the range of focus and degree of integration of disciplines Prior to the 1980s, most research looked at single commodities rather than systems, and methodologies, even when involving several disciplines, were focused on single components In soil sciences, most fertilisers trials were done with a 'rate, date and yield' methodology without addressing the whole cropping system and all available or potential plant nutrients sources In general, socio-economic analyses both of single crop profitability and wider systems issues were integrated to a very limited degree This has been progressively corrected with time, and particularly from the early 1980s with the introduction of farming systems research, but close integration of the various disciplines to address multiple components or research domains remains rare

Resource management research resulted also in an improved understanding of the hierarchy of physical constraints to improved crop yields, and challenge the notion that the zone is inherently one of 'low potential', at least in the technical sense Although rainfall limits the range of crops which can be grown and their potential yields, low soil fertility, and particularly soil nutrient deficiencies (nitrogen (N) and phosphorus (P)) and poor organic matter content are the limiting factors within a given rainfall zone Increases in soil fertility of elements other than those present in fertiliser packages are also critical to achieve the full benefit afforded by those applications When soil fertility is adequate, yields can double or triple with current technologies, even in areas with 400 to 500 mm of rainfall (Cisse 1986, Penning de Vries and Djiteye 1982)

THE CONSTRAINTS TO ADOPTION: IMPLICATIONS FOR POLICY AND RESEARCH

A substantial body of research exists on how to increase the adoption of technical packages First of all, the technology in question should be economically sound (generating sufficient gains in output to justify the cost of the inputs) In addition, there appears to be a need not only for the conditions of input supply to be assured, but also for price stability in output markets, at least for the time horizon needed to repay expenditures (Bosc and Hanak Freud 1995, Sanders *et al* 1996) These conditions match, essentially, those which have been responsible for the success of the Green Revolution in Asia. Economic studies of various crop packages indicate their potential profitability at the farm level (Sanders *et al* 1996), but cotton is the only widespread and sustained success story in intensification in West Africa It has benefited from a

solid 'enabling environment', i e availability of input credit and a guaranteed output price announced by the start of the growing season Similarly market oriented groundnut projects in the 1960s and 1970s were progressively dismantled, following output and marketing crises linked to drought and phytosanitary problems (rosette and aflatoxin) At present, price as well as institutional factors surely play a role in the choice of purchasing inputs A decline in the groundnut oil price (due to cheaper substitutes such as soya) combined with the elimination of fertiliser subsidies has resulted in a substantially less favourable input output price ratio, to the point where it is no longer clear that farmers will even break even when applying recommended doses

In contrast to these commercial crops, the food crops are generally sold in unregulated markets in this region and as such face potentially serious problems of output price instability The few cases of successful intensification have been confined to maize in the better-watered areas, linked either to very large urban markets and input subsidies (Smith *et al* 1994) or to the availability of inputs and assured revenues from cotton (Bosc and Hanak Freud 1995) For sorghum and millet, market development has been limited, as the growth of cities, and hence potential demand, has been accompanied by a shift in consumption patterns toward the 'convenience' staples of rice and wheat Experience suggests that it will be difficult to achieve widespread adoption of intensification packages for the cereals in the absence of an enabling environment Yet at present, the conditions of input supply are perhaps less favourable than at any time in the post-independence period, as seed supply, credit systems and subsidies have been dismantled in the context of structural adjustment programs Institutional and policy solutions will need to be found which can relax these constraints There may be some scope for promotion through the agro-industrial sector, but the key to breaking into the urban market is lowering production costs and improving the quality of the processed forms of flour used in the main dishes (couscous, tô, porridge) to make them more attractive to urban households than rice

Part of the problem with the current packages lies in the domain of technical risk, i e a wide range of uncertainty as to the actual yield gains to be attained if the technology is adopted There are two dimensions to this problem The first relates to the risks associated with rainfall failure, while recommendations are developed based on average rainfall conditions In the absence of crop insurance systems or possibilities for low-cost supplemental irrigation, there is little that can be done to get around this problem until advances in agro-climatology permit more reliable prediction of the onset of the rains, and hence season-specific advice on fertiliser applications, which are mainly applied at the beginning of the growing season The second dimension concerns the validity of the extrapolations used to determine the recommendation domains Too often, recommendations for a wide zone are developed based on a single or limited number of sites of experimental data, at the risk of not integrating the wide range of spatial and temporal variability of key bio-physical parameters (e g soil texture, nutrient and organic matter content, soil acidity) and other key land use systems parameters at

different scales (e g labour, manure and other inputs availability) which determine the level of yield response within the zone

Rural engineering techniques for soil conservation and water harvesting (e g 'zai' and bunds) have been adopted in some areas The limits to adoption appear to be related to their high labour costs and the frequent potential conflicts at the level of the farm community, since many farmers need to be involved in and agree upon techniques to be applied Rather than additional research, the priorities here are information dissemination, training of farmers, and raising the issue at the community level in areas where the potential gains are high

The virtual absence of farmer adoption of soil P amendment techniques, despite their diffusion in the context of development projects in various parts of the region since the early 1970s, reflects the difficulties of promoting technologies for smallholders which may be economically sound over a multi-year horizon, but with high up-front costs (Baanante 1996) This is an area where the research results are unambiguous and the recommendations unequivocal in most soils of the zone, rainfed agriculture stands to gain yield benefits from rock phosphate applications (from 20 to 300% depending on the crop and the degree to which other improved practices are associated), but in some cases these benefits appear only from the second or third year onwards Adoption appears to depend on the ability to find institutional solutions (multi-year credit, subsidies, distribution systems) to help farmers finance the investment and obtain the inputs

Farmers in the zone are fully aware of the benefits of using organic matter to improve soil fertility and raise yields, and the use of both farmyard manure and crop residues have been part of traditional cultural practices in many areas Research efforts have been addressed at ways of improving the quality of organic matter and optimising its use (Bationo and Mokwunye 1991), but have resulted in very limited adoption of the recommendations because they (1) are often based on experimental work which applied levels of organic matter unavailable at the farm level, (2) tend not to take into account the technical difficulties involved (e g incorporating crop residues into the soils), and (3) frequently failed to take into account the conflicting demands for sources of organic matter for other uses (animal feed, building materials, mulch) At the minimum, this translates into recommendations which have higher costs (since it is not only the labour involved, but also the opportunity cost of the source of organic matter that the farmer considers), if these opportunity costs are sufficiently high in relation to the farm's resource base, they may entirely preclude adoption

In discussions on RM recommendations in the zone, one frequently encounters a debate juxtaposing 'productivity-raising' and 'conservation' techniques, but this is a false debate The complementarity between inorganic and organic fertilisers for long-term fertility management has been clearly established Moreover, intensification increases the availability of organic matter which is currently in short supply The most severe problems of soil erosion requiring conservation techniques occur in the better

watered zones which not only have the highest yield potential, but have already been the scene of the most successful cases of intensification (in cotton and maize) to date

FUTURE RESEARCH THEMES, APPROACHES AND METHODOLOGIES

The solutions to some obstacles in resource management lie largely in the hands of research, which needs to be shifted in perspective and orientation The shift in perspective is to enlarge the view of the agricultural system and its available resources this will frequently involve consideration not only of resources at the farm level, but also at the community or even across larger areas, when common pasture lands are involved It implies also to look for the-best-for-most stakeholders ('win-win' situations) rather than compromises The shift in orientation is to concentrate on the integration of animal husbandry and cropping systems, since the increased availability of organic matter for crops will necessarily involve more intensive management of livestock as well, including use of forage crops

In looking ahead, it is incumbent upon RM research to consider two essential points for future RM research (1) the decline in funding available at the regional level makes it all the more important to orient work in line with the main priorities and to avoid duplication, (2) there exists a substantial backlog of research results which have not been fully exploited and which can serve as a starting point Based on the analysis of adoption issues, four priority themes for RM research in the region are identified

1) Reducing the costs of mineral fertilisation via the use of less costly forms than the compound formulas commonly recommended in packages such as single-source and less processed fertilisers,
2) Increasing the efficiency of plant water and nutrient (particularly N and P) uptake through the development of varieties (identification and exploitation of plant's genetic capabilities), complementary soil management techniques, and targeting of varieties to specific environments,
3) Increasing the availability of organic matter through integration of animal husbandry and cropping systems (including use of forage crops and establishing a better balance between cropping and pasture areas at the farm and community level),
4) Increasing water availability, through exploration of the possibilities for small-scale supplementary irrigation in areas where water resources permit this

Multi-disciplinary approaches will be necessary to tackle these themes This is evident in areas such as increasing the efficiency of plant water and nutrient uptake (which at the minimum involves breeders, soil scientists and agro-physiologists) or organic matter themes (which will involve soil scientists, livestock scientists and forage specialists) However, it cannot be sufficiently stressed that there is a need to incorporate economic (and for some themes rural sociologic), and spatial and temporal (short and long-term) analyses at various stages of the research The record also highlights the need to address these themes with explicit consideration of the domains of applicability of recommendations to reduce the technical risks associated with them The availability of new

research tools, such as modelling, geo-statistical analysis, and spatialisation techniques (including GIS) should facilitate this work (van Duivenbooden 1997) Although the RM research agenda clearly should involve field and laboratory experimentation, it should be possible to move ahead both more quickly and at lower cost by better exploiting the existing data bases, also in the broader context of the zone A priority for the regional research agenda is to make this information available in a usable form Three key areas are soil fertility parameters directly affecting crop production (percentage of fine particles, organic matter, pH and plant available nutrient content), performance records of varieties according to different production environments and the multi-scale characterisation of the biophysical, socio-economic and policy environment

Research efficiency can also be enhanced through more effective partnership mechanisms among the various research institutes, and the relevant non-governmental organisations (NGOs) At the minimum, there is a need for frequent exchange of results and ideally a mechanism to consult and coordinate amongst each other in the process of planning and experimental design so that research activities are 'aligned' among groups pursuing common goals Although various formal and informal networking mechanisms do exist, their benefits to date in the area of RM research appear less substantial than in the area of crop improvement The issue is not necessarily to create new networks, but to see how RM themes can be better taken into account in the context of existing mechanisms, including the crop specific networks Likewise, effective participation of the farm community and the extension services (particularly through on-farm trials) is an essential component of the results-oriented RM research agenda

CONCLUSION

The challenge for resource management is to put into place an enabling environment for intensification, involving both short and long-term management techniques While parts of this challenge lie with the policy community, research has a direct role to play in reducing the technical risk of recommendations, reducing the costs of the packages and, in the particular area of organic matter management, developing improved techniques at the community level This task will be facilitated by effective partnership across disciplines and across institutions, better exploitation of existing experimental data and judicious use of new computer-based techniques to complement (and in some cases replace) field experimentation Although sustainability per se is an important goal, the concept of market-oriented development will need to guide both policy makers and researchers, in as much as this appears to be a precondition for widespread intensification

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