Cereal technology development in the Sahel

Burkina Faso and Niger

Robert R. Deuson and John H. Sanders

Soil fertility has been declining in the Sahel as a result of increasing population pressure. Water is also scarce, and an adequate supply of water is required if crops are to respond favourably to the application of fertilizer. Combined soil and water management practices must thus be introduced, and this will require vigorous public sector support. At present there is no cost-effective alternative to the use of imported chemical fertilizer, but long-term research can focus on this problem.

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[1] L. Ames, 'A preliminary report on the evaluation of new technologies in Burkina

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The conventional wisdom on sub-Saharan African agriculture is that this is a land-surplus region with the principal constraint being seasonal labour availability. However, in spite of substantial governmental promotion since the second world war in many countries of animal traction and other labour-substitution techniques, adoption of these technologies has been minimal. Based upon farm testing of new technologies and field observations of farmers' practices, the two principal constraints to cereal-yield increases in the semi-arid Sahel appear to be water availability and soil fertility. To implement techniques to overcome these constraints, farmers will often encounter the problem of seasonal labour scarcity. However, it is the combined effects of more available water and improved soil fertility that can substantially increase cereal yields.

The first section summarizes the recent developments causing a breakdown of the traditional method of restoring soil fertility. The second section discusses the water availability/soil fertility constraints. In the last sections some implications are drawn for agricultural policy and research and development planning with respect to new technologies to overcome these constraints.

Farmers' response

In both Burkina Faso and Niger, with increasing population pressure, farmers have been shortening the traditional fallow system. The decline of the fallow system has not been replaced with the utilization of chemical fertilizer except in higher-rainfall regions such as south-west Burkina Faso. Hence, soil fertility has been declining and soil erosion accelerating. As the land quality deteriorates, cereal yields have been falling and the more stress-tolerant millet is replacing sorghum.[1] On the sandy dune soils millet is already the predominant crop and there are only very small areas of sorghum such as below the legume trees and on the water recession areas. With declining soil fertility, farmers expand into more marginal agricultural zones to maintain the desired levels of cereal consumption. Introducing livestock and legumes are feasible activities to increase organic matter content and improve soil fertility levels. However, cereal production objectives come first for the Sahelian farmer before he can introduce more animals or more complicated rotations with improved legumes.

The Sahelian farmer combines crops and cultivars of different season length to take advantage of differ-

ences in soil quality and as a portfolio decision. Long-season cultivars have higher yield potential but are riskier in bad years. The farmer has a range of locally adapted cultivars on his farm and in the region. Over the last decade shorter-season traditional cultivars of sorghum and millet have been widely disseminated in Burkina Faso.[2] A similar phenomenon is occurring with short-season cowpeas developed by the public sector in Niger. In another long period of better weather, such as the 1950s and 1960s, a shift in cultivar portfolio mix back towards the longer-season cultivars would be expected.

Small farmers often extensify or increase their cultivated areas to attain their cereal consumption goals. This strategy further depletes and degrades their limited soil resources. Purchasing inputs to increase soil fertility is risky because of the variation in water availability and other stochastic factors, especially the large variations in output prices. Hence it will be necessary to develop an integrated technology development programme to respond to this crisis of declining cereal yields and depleted soil resources.

New cereal technologies for the Sahel

In the semi-arid regions the importance of water availability is clear from the definition of the region. However, increased water availability needs to be combined with higher plant-nutrient levels to increase cereal yields as the soil levels of N and P are generally very low. Since the response to fertilizer is dependent upon the plants having sufficient water available at the critical growth stages, fertilization without increased water availability is too risky for most farmers in the semi-arid regions. The combination of methods to overcome both of these constraints has been shown to increase yields and to reduce risks from fertilization alone, both over time and across farms in repeated trials in Burkina Faso.[3] These combined innovations have also been estimated to be highly profitable, except in very good rainfall years when farm-level cereal prices collapse.[4]

Presently, one water-retention technique of constructing ridges on the contour is being rapidly introduced by farmers with public agency support in the depleted soils of the Central Plateau of Burkina Faso.[5] The effect of this technique depends upon the distance between the ridges and whether it is combined with soil fertility improvements. One advantage of this ridging is that the labour for it can be done in the dry season. Other water-retention techniques, such as tied ridges and improved land preparation, have shown a larger effect on yields in repeated farm-level testing but these techniques need to be undertaken during the crop season when labour demands for agriculture are higher.[6] Even in the extremely degraded soils, where rainfed cultivation of sorghum was previously not feasible, there are techniques to capture water and recover soil, such as using demilunes. In Niger the techniques have enabled a return to cereal cultivation in some areas.[7]

This combination of water retention and chemical fertilizer has a large yield effect on the heavier soils where crusting frequently reduces infiltration. On the sandy dune soils there is a different problem of retaining water around the crop roots. Here the same principle of combining water retention and soil-fertility improvement has been obtained with higher plant densities and chemical fertilizer.[8]

Due to the cash expenditure, the risk and the requirement that chemical fertilizers be available to farmers at specific times, there has been substantial interest in the Sahel in research on alternatives to chemical fertilizer, especially on animal manure, crop residues and rotations (see Table 1). Outside the Sahel there has been experiment-station research on biological nitrogen fixation and on mycorrhizae. In the last decade there has been experiment-station and farm-level testing in the Sahel of the local rock phosphates.[9] Recent research in Niger indicates that the high-quality rock phosphate from Tahoua, even when partially acidulated, can be competitive with imported super-simple phosphate only if supplied to farmers at approximately 25% of the price of commercially imported super-simple

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Faso', mimeo, Department of Agricultural Economics, Purdue University, West Lafayette, IN, USA, 1986.

[2] H.I.D. Vierich and W.A. Stoop, 'On-going changes in the West African savanna agriculture in response to growing population and continuing low rainfall', mimeo, ICRISAT, Patancheru, Andhra Pradesh, India, 1987.

[3] J.G. Nagy, J.H. Sanders and H.W. Ohm, 'Cereal technology interventions for the West African semi-arid tropics', *Agricultural Economics*, Vol 2, 1988, pp 197–208.

[4] J.H. Sanders, 'Agricultural research and cereal technology introduction in Burkina Faso and Niger', *Agricultural Systems*, Vol 30, 1989, pp 139–154.

[5] J.H. Sanders, J.G. Nagy and S. Ramaswamy, 'Developing new agricultural technologies for the Sahelian countries: the Burkina Faso case', *Economic Development and Cultural Change*, July 1990.

[6] For a summary of water-retention techniques see W.G. Matlock, 'Five small-scale water management technologies', mimeo prepared for the Office of Technology Assessment, Congress of the United States, Washington, DC, USA, 1987.

[7] C. Reij, P. Mulder and L. Bagernann, *Water Harvesting for Plant Production*, Technical Paper No 91, World Bank, Washington, DC, USA, 1988. See also H.E. Dregne, 'Aridity and land degradation', *Environment*, Vol 27, No 8, October 1985, pp 16–20, 28–33.

[8] International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center, *Annual Report, 1984*, Niamey, Niger, 1985; *Annual Report, 1985*, Niamey, Niger, 1986; *West African Programs, Annual Report, 1986*, Niamey, Niger, 1987.

[9] P.L. Vlek, A.U. Mokwunye and M.S. Mudahar, 'Soil fertility maintenance in sub-Saharan Africa', mimeo prepared for the Office of Technology Assessment, Congress of the United States, Washington, DC, USA, 1987.

Table 1. Some relevant water availability and soil fertility alternatives for the Sahelian countries.

Water availability

Water conservation techniques
- Dikes
- Improved land preparation
- Rainfall harvesting techniques
- Tied ridges

Irrigation
- Large projects
- Micro irrigation, eg wells
- Supplementary

Crop breeding
- Drought tolerance

Soil fertility improvements

Inorganic fertilizer
- Imported
- Locally available (rock phosphate)

Organic fertilizers
- Manure
- Incorporation of plant residues
- Alley cropping

Alternatives to fertilization
- Improving traditional alternatives
  - Crop rotation
  - Intercropping
  - Fallow periods

Crop breeding
- Low P tolerance
- Tolerance to aluminium

Sophisticated new technologies
- Inoculation of legumes for improved N fixation
- Mycorrhizae

phosphate. This implies that at present efficiency levels the rock phosphate is not likely to become competitive with the imported chemical.[10]

In spite of this farm-level and experiment-station research, the utilization of organic and local inorganic fertilizers appears to be slightly declining in the semi-arid Sahel. As communal grazing land becomes less available, there are fewer animals. Many technical and economic problems of these alternatives to improved chemical fertilizer have not been resolved.[11] Over the next decade the principal method of improving soil fertility in the Sahel will need to be the importation of chemical fertilizer. The principal nutrient deficiencies are presently P and N and inorganic fertilizers are the most concentrated and lowest-cost sources presently.[12] Organic fertilization can supplement this effect and improve water retention and trace elements. Hence, at the low levels of soil nutrients in most of the Sahel, inorganic and organic fertilizers will be complements, not substitutes.

Policy implications

New agricultural technologies in the semi-arid Sahel need to focus on improving the agronomic environment to enable sustainable cereal-yield increases. The priority suggested here and elsewhere[13] is to simultaneously apply new soil- and water-management techniques. Currently the use of fertilizer in sub-Saharan Africa is the lowest in the world – about 2.8 kg per ha of agricultural land or one-tenth of the level in India.[14] In the best agricultural region of Burkina Faso chemical fertilizer consumption has been declining slightly on a per-farm basis with the gradual elimination of fertilizer subsidies since 1984.[15]

Producers adopting new combined soil-fertility and water-conservation technologies face a learning curve. The management requirements of introducing these technologies simultaneously are high; hence farmers are expected to obtain the full benefits of the new cost-reducing technologies only gradually. Some facilitation of the introduction of these technologies by the public sector seems to be appropriate. These could be farm-level demonstrations and public help in implementing the water-retention measures, as with the contour ridges in Burkina, or more public investment in infrastructure development to improve input and product markets, or temporary subsidies on inputs.

Conclusions

In the higher-rainfall region of Burkina (above 800 mm of annual rainfall at 90% probabilities) there has been rapid agricultural development based principally upon cotton yield improvements and substantial increases in chemical-fertilizer consumption. In the lower-rainfall regions (500–800 mm) the combined technologies of water retention and moderate fertilization have the potential to increase cereal yields by 50–100%. Since farmers find it difficult to introduce several new technologies simultaneously, some public support is suggested. However, the technological and economic potentials for substantial cereal yield gains have been demonstrated. It is time to be more optimistic about the potential in the Sahel for cereal yield increases and to promote combined technology introduction more aggressively.

Research programmes can usefully search for alternatives to chemical fertilizer. Lower-cost alternatives to chemical fertilizer proposed presently have either management or technical problems or are actually more expensive.[16] Based upon present scientific knowledge and economic feasibility, action programmes to increase cereal yields in the Sahel now will need to utilize chemical fertilizers and some water-retention techniques. Development programmes need to move ahead by promoting chemical fertilizer rather than waiting for the 'magic', low financial expenditure, no foreign exchange requirement substitute for chemical fertilizer. The long-run goals of research should not impede the short-run objective of increasing cereal yields now. Scarce foreign exchange will need to be utilized and marketing infrastructure improved for the more timely availability of fertilizer and to handle increased cereal supplies.

[10] P.A. Jomini, 'The economic viability of phosphorus fertilizer in southwestern Niger: a dynamic approach incorporating agronomic principles', unpublished PhD thesis, Department of Agricultural Economics, Purdue University, West Lafayette, IN, USA, 1990.
[11] Nagy *et al, op cit*, Ref 3.
[12] Sanders, *op cit*, Ref 4.
[13] R.R. Deuson and J.C. Day, 'Transfer of sustainable technology in dryland agriculture: lessons from the Sahel in the 1980s', *Agricultural Economics*, forthcoming; and T.S. Jayne, J.C. Day and H.E. Dregne, *Technology and Agricultural Productivity in the Sahel*, US Department of Agriculture, Agricultural Economics Report No 612, US Government Printing Office, Washington, DC, USA, 1989.
[14] M. Yudelman, *Prospects for Agricultural Development in Sub-Saharan Africa*, Occasional Paper, Winrock International Institute for Agricultural Development, Morrilton, AR, April 1987.
[15] J.H. Sanders, P. Wright, P. Granier and K. Savadogo, 'Resource management and new technologies in Burkina Faso for a stable agricultural development', Report to the West African Division of the World Bank, Department of Agricultural Economics, Purdue University, IN, USA, 1987.
[16] Nagy *et al, op cit*, Ref 3; Vlek *et al, op cit*, Ref 9.

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