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Edited by
Allen Maunder, Institute of Agricultural Economics, University of Oxford, England
and
Ulf Renborg, Department of Economics and Statistics, Swedish University of Agricultural Sciences, Uppsala

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Gower

HANS P. BINSWANGER AND PRABHU PINGALI

Agricultural Intensification and Technical Change in Sub-Saharan Africa

This paper provides the main conclusions of a research project on the evolution of farming systems and agricultural technology in sub-Saharan Africa. These conclusions are based on a detailed literature review complemented by field visits to 50 villages in 10 countries of sub-Saharan Africa. We explore the impact of population growth and/or improvements in market access on the overall nature of the farming system, on land use patterns and yields, on the use of mechanical technology and the production of organic fertilizers, and on the institutional restrictions to the acquisition of land.

African farmer-generated solutions to increasing food production from a given area of land have been identical or strikingly similar to the solutions found in other parts of the developed or developing world. Farmers respond to increasing population densities and/or increased demand for agricultural output with an expansion in the area cultivated, an increase in land investments and innovations in mechanical technology and manuring systems. These changes are capable of sustaining slow and steadily growing agricultural populations with modest increases in agricultural output.

This research supports the view that more rapid growth in output can be achieved where agricultural policy promotes: (a) an expansion in transport infrastructure; (b) the installation of core agricultural support services; (c) trade policies that do not restrict the availability of new technology; and (d) a rational agricultural price policy that does not suppress farmer initiative for expansion in output. Appropriate agricultural policies could lead to rapid expansion in food output resulting in higher levels of food consumption and increase in income per caput[1].

Population growth and market access are the main determinants of agricultural intensification

Agricultural intensification is defined here as the movement from forest and bush fallow systems of cultivation to annual and multicrop cultivation systems where plots of land are continuously cultivated. The existence of

a positive relationship between population density and agricultural intensification has been hypothesised by Boserup. An increase in population density causes a reduction in fallow periods due to increasing land scarcity, hence the movement to more permanent cultivation of land. Our research in addition to verifying the Boserup hypothesis also finds improvements in market access (through better roads and transport facilities) to have a similar positive effect on the intensity of land-use. Intensification in the latter case occurs because: (a) higher prices and elastic demand for exportables implies that the marginal utility of effort increases, hence farmers in the region will begin cultivating larger areas; and (b) higher returns to labour encourage immigration into the area from neighbouring regions with higher transport costs. We have not come across any cases of sparsely populated areas under forest or bush fallow systems. Presumably, the former could occur if market access is excellent, while the latter could not occur even under poor market conditions.

Heavier soils are used only under high population densities or where market access is good
Heavier soils are the ones which are deeper and have a higher clay content; these soils therefore have higher water and nutrient holding capacity. Although these soils provide a higher and more certain yield they are often impossible to cultivate in the absence of investments in water control and drainage. Therefore, under low population densities and in the absence of animal or motor power more easy to work soils with a low clay content are preferred over the deep clayey soils. As population densities increase the heavier soils are intensively cultivated due to the relatively higher returns offered to labour, fertilizer and land investments, especially for rice cultivation. Also, as population densities increase labour supply increases, making it possible to undertake the labour investments in irrigation, drainage etc. Therefore, population pressure leads to a reversal in preference (price) of different types of land with the deeper heavier soils being preferred over the lighter more easy to work soils.

Agricultural intensification leads to an increase in yields per hectare
The higher yields are obtained due to two reasons: (a) the movement to heavier soils which are more responsive to intensification; and (b) more careful husbandry of existing fields. However, intensification of farming in the absence of a new power source (animal or motor power) could lead to a decline in yield per man-hour. This is because the heavier soils require high levels of power for land investments and land preparation and because sustaining yields on existing soils requires extremely labour intensive manuring and interculture.

Agricultural intensification, in the absence of labour-saving technical change, leads to an increase in agricultural employment
The total labour input per hectare is positively correlated with the intensity

of farming, holding technology constant. The movement from forest fallow to annual cultivation in West Africa using the hand hoe results in an increase in total labour input per hectare from 770 hours in Liberia to 3,300 hours in Cameroon (Ruthenberg 1980). Increased labour is required for investments in irrigation, drainage, levelling or terracing and for the development of more evolved manuring techniques. In addition to these overhead labour requirements permanent cultivation also warrants extremely labour intensive land preparation and interculture.

Organic fertilizer use is positively associated with land scarcity
In land abundant areas long-term soil fertility is maintained by periodic fallowing of land. As the fallow periods become shorter due to an expansion in the area under cultivation the use of organic fertilizer begins to emerge. At first these fertilization techniques are fairly rudimentary, often involving no more than a periodic transport of household refuse to the fields. As farming intensifies more evolved composting and manuring techniques are used. Under extreme land scarcity one observes the incorporation of legumes in a crop rotation cycle as green manure. At this stage also one tends to observe increased use of chemical fertilizers as a substitute for labour intensive manuring techniques. Such general use of chemical fertilisers is still very rare in sub-Saharan Africa although the use of fertilizers for select crops such as cotton and groundnuts which are produced for the market is becoming increasingly common.

The transition from hand hoes to animal-drawn ploughs is only profitable at higher intensities of farming
The transition from digging sticks and hand hoes to animal-drawn ploughs is closely correlated with the evolution of the farming system and cannot be understood by using a simple choice of techniques analysis familiar to economists. This transition would not be cost-effective in forest and bush fallow systems due to the very high labour requirements for destumping and levelling the fields. As the length of fallow decreases the costs of destumping decline because of reduced tree and root density. Destumping requirements are minimal by the grass fallow stage and it is here that animal power becomes the economically dominant technology. Also, by the grass fallow stage trypanasomiasis becomes less of a constraint on animal ownership and use and grazing land becomes prevalent. The transition to animal-drawn ploughs would occur first on soils which are hard to work by hand (clays) because the returns to ploughing are highest on these soils. It is only later that animal-drawn ploughs are used on all other soils. The use of animal-drawn ploughs leads to substantial labour savings and a timely completion of the land preparation operation.

Lack of animal husbandry/mechanical skills are at most a short-run constraint to the use of animal/tractor power
Our study finds that, where conditions were appropriate, African farmers acquired the skills required for operating animal draught/tractor

equipment readily. Moreover, we found that many of the skills required for the efficient use of animal draught/tractor equipment had been acquired by these societies prior to the acquisition of this equipment. For instance, a majority of the tribes in sub-Saharan Africa (outside the humid forest zone) are crop cultivators who keep cattle for milk, meat and as a store of wealth. These farmers already possess animal husbandry skills, although they may lack the ability to train their animals for draught purposes. As farming intensifies, however, they acquire this additional skill and begin using animal-drawn ploughs. Even in the humid forest zone where trypanosomiasis caused a historic absence of livestock we found that farmers could and did acquire livestock husbandry skills, when it was possible and profitable to do so. Similarly, the use of bicycles, motorcycles and mechanical mills has become very common all over sub-Saharan Africa, even in areas where animal traction and tractors are not used. The mechanical skill required for the use of this equipment is as complex as that required for animal-drawn implements and perhaps even tractors. We also found that where animal draught or tractor equipment was in use, workshops capable of servicing this equipment emerged fairly rapidly and were located within accessible distance of the users.

In general, it is economically infeasible to bypass the animal traction stage and move directly to tractors

This is because the quality and hence the cost of destumping is much higher for tractor operations than for animal-drawn ploughs. Tractor operations also require more elaborate systems for repair and maintenance. Moreover, the societies concerned are usually characterised by extreme capital scarcity and cannot usually afford the substantially higher capital costs associated with tractors. Once animal draught power has been successfully incorporated in the farming system, however, tractors and animals become close substitutes for ploughing. The choice of techniques analysis finally becomes relevant. The factors involved are the relative costs of land, labour and capital, the seasonality of agricultural production and the cost of tractors. There are two exceptions where the direct transition to tractors may be cost-effective: (a) valley bottom lands where irrigated or flooded rice is cultivated; and (b) the grassy savannas in the semi-arid zone. In both cases the land is open and grassy and hence destumping is not a major problem. The profitability of using tractors, however, continues to depend on domestic and external market demand.

The profitability of animal/tractor-drawn equipment is constrained by the length of the growing season.

The length of the land preparation period is an important determinant of the capacity utilisation of animal and tractor-drawn ploughs. Utilisation rates are lower the shorter the period of land preparation, accordingly, costs per unit of equipment are higher the shorter the season. The period

during which mechanical tillage equipment can be used in the arid and semi-arid tropics is extremely limited. Timeliness of ploughing is crucial to assure adequate time for crop growth before soil moisture stress becomes a problem. Due to the acute timeliness problem in the dry tropics, rental markets for equipment are not well established and therefore equipment costs cannot be spread over a larger area. Longer ploughing periods exist in the sub-humid and humid tropics, in areas with a bi-modal rainfall regime and in high altitude areas. Well developed rental markets exist in these areas and the cost of equipment is spread over several users. In the case of tractors, capacity utilisation can be increased by providing contract hire operations across several rainfall zones.

It is not unusual for some intensively cultivated regions to persist in the use of hand hoes

The tropical highlands are a primary example of intensively cultivated areas that persist in the use of hand hoes. There are two reasons for the continued use of the hoe in the highlands: (a) the steep terrain is often a constraint on the use of animal/tractor power; (b) the tropical highlands have a comparative advantage in the production of tree crops rather than field crops and therefore the opportunities for the use of mechanical tillage equipment is limited. Although small quantities of field crops are grown for subsistence purposes the plot sizes are small and the season length is long, therefore hoes continue to be the dominant technology.

The simultaneous transfer of all agricultural operations to a new power source (animal or motor) is not economically attractive

Agricultural operations can be grouped in terms of the relative intensity with which they require power (or energy) relative to the control functions of the human mind (or judgement). Operations such as land preparation, transport, milling, grinding and threshing are power-intensive, while weeding, sifting, winnowing and fruit harvesting are examples of control intensive operations. New power sources are always used first for power intensive operations even when wages are low. It is for these select operations that the use of the new power source has the highest comparative advantage. The transfer of control intensive operations to the new power source becomes profitable only when wages are high or rising. In land-scarce economies where non-agricultural demand for labour is low, operations such as weeding, interculture and harvesting continue to be done by human or animal power. Therefore, agricultural projects which promote a package of equipment designed to mechanise all agricultural operations usually fail.

Specific rights to land become well defined only in the face of land scarcity

The institutional arrangements for the acquisition of land by individuals within a society and by 'outsiders' are not rigid but change as increasing population densities or improved market access make land scarce. In land

abundant economies cultivation rights are easy to obtain, often for no more than a nominal gift to the head of the lineage. Land acquisition becomes more and more difficult as intensification leads to more narrowly defined groups or lineages and therefore results in the exclusion of large numbers of people from acquiring the rights to cultivate. The ultimate institutional change, and one which commonly occurs under high population densities, is one of clearly defined rights to cultivate specific plots of land often with the ability to buy and sell land. The above institutional changes in land acquisition induced by population growth were already outlined by Boserup in 1964. During our field visits we asked a series of questions that allowed us to determine the process of land acquisition in a particular society. Our findings support Boserup's theory on population growth and rights to land. The transition to specific land rights improves incentives to undertake investments which are required for the intensification of production and preservation of fertility.

NOTE

[1]For a detailed account of the methodology and findings of this study, see Pingali and Binswanger (1984) and Pingali, Bigot and Binswanger (1985).

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DISCUSSION OPENING – A. T. BIROWO

In general I should like to admit that I know very little about agriculture in Africa. If I may put some comments at all, it is because I have some experience in development administration and research on similar issues in Indonesia and in other Asian countries.

Professor Idachaba has put forth a comprehensive paper on issues in redirecting agricultural research, extension and training to achieve accelerated agricultural development in sub-Saharan Africa. The paper has indeed unveiled important issues in research management to meet the challenges in efforts to realise the production potential for food and

agricultural development. It is interesting to learn the recognised facts that as a colonial heritage research was initially directed to meet the needs of the colonial powers in Europe, instead of directly formulated to meet the needs of national agricultural development. It also explains why data on the socio-economic environments of the research systems in the independent nations of present sub-Saharan Africa are not clearly unveiled. At the present level of economic development of the regions, social and institutional environments are very important determinants of the agricultural research system. Whether the research system is under the jurisdiction of the Ministry of Agriculture or Ministry of Science and Technology, depends on the socio-economic environment. One thing is certain, one needs to have an explicit national science and technology policy of which national agricultural research policy is a part, as the author has rightly mentioned. The need to monitor and periodically evaluate the programme is beyond question. In the face of obvious scarcity of research managers and research skill the fragmentation of previous institutes into scattered 'national' institutes is to be discouraged. Indeed I support the author in proposing relocation of the centre to make efficient use of scarce skilled resources.

I do not agree with the so-called 'perennial' mistakes as being too much concentration on 'supply research' which actually should address demand aspects as well. Within the current socio-economic context it is only natural that supply issues come forth more apparently than demand problems. The market aspects are organised by few elements and may be relatively imperfect, whereas supply problems are technically more apparent.

The authors of the second paper have richly disclosed important facts and analyses from empirical research on sub-Saharan agriculture. The issues are very close to my heart as we have many similar problems with rice intensification in Indonesia. I am particularly interested in the propositions relating to the process of technology transfer, especially the social and institutional aspects. In my opinion it is rather dangerous to move directly to tractors and to bypass the animal tradition. The penultimate finding indirectly supports this. I would, however, question the last statement. In our experience, in the social setting of Indonesia, specific rights to land became well defined in areas where land was not scarce. It seems to depend on the social institutions and levels of economic development. Since information on this is incomplete, perhaps the authors may give a further explanation.

GENERAL DISCUSSION – RAPPORTEUR: J. L. STANNING

The discussion of the first paper was opened by a speaker from the floor who commented that whilst the paper had outlined five possible sources of incremental agricultural production he wanted to know which of these measures was of immediate relevance to the present food crisis situation

in sub-Saharan Africa. Other speakers questioned whether the poor production performance was related to poor research performance. Concern was expressed about the apparent past failure of international and national agricultural research programmes to provide appropriate technological packages to realise the production potential in Africa. How could national agricultural research programmes be made to function more effectively and how should critical areas for research be identified?

The second paper provoked controversial discussion and a number of questions were raised. In view of the observations regarding institutional arrangements with respect to land, the authors were asked to comment on the effects of increasing population density and market access on land use beyond the intensification issue emphasised in the paper. Another speaker asked whether the observed topographic effect illustrated by rice was also the case for traditional African crops like sorghum, millet and root crops. There was disagreement with the statement that it was economically infeasible to bypass the animal traction stage. The authors were asked if they were aware of the tsetse fly problem and it was suggested that although tractors might be more costly than animal traction they were a more feasible alternative in tsetse-infested areas. More details were also asked for concerning the survey techniques used in the research reported in the paper.

In reply to the questions raised, Professor Idachaba emphasised the need for national research programmes to pay greater attention to the research demands of small farmers. He suggested that in this regard farm systems research might have an important role to play in articulating the research demands of small-scale producers. Turning to immediate priorities, he said that each country had to identify its own commodity priorities for research and that factor endowments also had to be taken into account. Since in many African countries labour was a production constraint, greater emphasis in national research programmes should, in his view, be placed on researching appropriate labour-saving technologies. Finally, he stressed that effective linkages between research workers, executive ministries and private research organisations was a key factor in making national agricultural research systems more effective.

Dr Pingali responded by explaining that cross-sectional surveys were the basis of their study although some time series surveys had been possible at particular locations (for example in Tanzania). He felt that where data sources for time series surveys were available this could be an interesting avenue of further study. More research was also required concerning the effect of agricultural intensification on land tenure patterns, on land rental and ownership exchange markets, and on land consolidation and fragmentation. It was confirmed that the topographic effect was observable for traditional African crops such as millets and sorghum. He maintained the view that it was economically infeasible to

bypass the animal traction stage and argued that the widespread failure of tractor projects in tsetse areas supported this thesis.

Participants in the discussion included L. A. Msambichaka, S. Bellete, J. C. Martinez, S. Simons, Sara J. Scherr and J. A. Akinwumi.