

Toward sustainable intensification of agriculture in sub-Saharan Africa

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Abstract Across the African continent efforts to intensify agriculture have been limited to specific commodities, locations or particular production schemes. The causes for the widespread failure to overcome low land and labor productivity while maintaining ecosystem services have often be analyzed but remain poorly understood. A social-ecological system approach may help to better understand the complex nature of ecological disadvantages, postcolonial structures, limited connect between producers and consumer markets, low off-farm livelihood opportunities, partial underpopulation and lacking experience with the concept of sustainable production as a major impediment for sustainable intensification of the agricultural sector. Nevertheless, recent success stories in agro-pastoral systems as well as urban vegetable and animal production and associated value chains in West Africa, and in intensive mixed-cropping systems of the Great Lakes Region show the potential of stakeholder-driven agricultural intensification. Proper interpretation of these cases may provide lessons for a more widespread eco-intensification of smallholder agriculture in sub-Saharan Africa.

Keywords colonial heritage, land use, marketing, property rights, subsistence agriculture, urbanization, value chains

1 Intensification of African agriculture

After the formal end of the inner-African and intercontinental slave trade and the onset of the colonial conquest of Africa by European powers in the late nineteenth century, the continent was perceived opportunistically by rivaling

territorial powers as a provider of raw materials and specialty goods, as well as a market for the raising mass production of trade items. Deliberately discouraged was the development of local industries which never became competitive given small local markets. At the same time intensification of agriculture focused on export commodities such as palm oil (*Elaeis guineensis*), cocoa (*Theobroma cacao*) and rubber (*Hevea brasiliensis*) in West Africa, cotton (*Gossypium hirsutum*) in North and West Africa, and irrigated rice (*Oryza sativa*), maize (*Zea mays*) and wheat (*Triticum aestivum*) on prime land across the continent to feed settlers and the small middle class. Well known large-scale examples of these efforts are the cotton, groundnut (*Arachis hypogaea*), and sorghum (*Sorghum bicolor*) production in the Gezira irrigation scheme of Sudan^[1] and the cotton and rice production in the Office du Niger in Mali. Until the late 1960s, in contrast, smallholder-oriented intensification of the cultivation of staple food crops, such as millet (*Pennisetum glaucum*), sorghum, African upland rice (*Oryza glaberrima*) and cowpea (*Vigna unguiculata*), for the poor African population was neglected. These species are typically cultivated on highly weathered soils throughout the large drylands of the Sudano-Sahelian zone and nearby uplands. Similarly, starchy tubers or root vegetables, such as potato (*Solanum tuberosum*), cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), yams (*Dioscorea*) and taro (*Colocasia esculenta*), are widely grown in smallholder agroforestry systems typical for the humid tropical zones. It was only 20 years later that the initiatives of the Green Revolution triggered by the work of three of the four Africa-based centers of the Consultative Group on International Agricultural Research (the International Institute of Tropical Agriculture (IITA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center, and AfricaRice) started to advocate the combined use of organic and mineral amendments to intensify the production of staples on the predominantly

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sandy dryland soils. Over the last two decades these efforts developed into so called integrated soil fertility management schemes that focus on soil health. In recent years digital infrastructure became increasingly important in these endeavors^[2]. The intensification of cropping systems was accompanied by livestock systems research of the International Livestock Center for Africa (ILCA) and the International Laboratory for Research on Animal Diseases (ILRAD) that were merged into the International Livestock Research Institute (ILRI) in 1994 for the improvement of livestock genetics and nutrition as well as animal health. In cooperation with national agricultural research institutions, livestock breeding programs, feed improvement strategies, supplement feeding and women-centered small-stock husbandry programs were promoted. These were combined with vaccine development, vector reduction to combat major zoonoses and, more recently, livestock insurance programs^[3]. A strong focus was laid on mixed crop-livestock systems that were perceived as a motor of sustainable rural development^[4]. However, with the exception of chicken, the yield of meat per animal has not increase since 1960, and although milk yield per cow ($\text{kg}\cdot\text{yr}^{-1}$) nearly doubled in the past 60 years, the current yield ($1200\text{ kg}\cdot\text{yr}^{-1}$) is only half of the global average ($2580\text{ kg}\cdot\text{yr}^{-1}$) and about a fifth of China's current per cow production of $5600\text{ kg}\cdot\text{yr}^{-1}$ ^[5].

In the context of the Millennium Development Goals ongoing research and development efforts were packaged into large-scale, community-based, integrated rural development approaches, such as advocated by the Sasakawa Global-2000 Millennium Villages Project^[6], and since 2006 the Alliance for a Green Revolution in Africa

(AGRA), initiated by the Gates Foundation^[7]. As a prerequisite for sustainable agricultural intensification in rural areas, the latter initiatives advocated the need for a big push approach combining established Green Revolution schemes with support for market development and the local health and education sector.

Despite the widespread efforts to transform African agriculture from a largely subsistence-based mode of land use toward a sector with more commodity-oriented business models, productivity of both land and labor are still the lowest worldwide (Fig. 1). Also food sufficiency and sovereignty remain problematic throughout most of the continent. Outside the aforementioned sector of export-oriented cash crop production, traditional African agriculture is characterized by a low degree of mechanization as a consequence of (1) small plot size and lack of a local machinery industry, (2) a complex system of land tenure (interaction of customary, personal, tribal and governmental rights), and (3) small consumer markets for locally traded food products given a predominantly agricultural populace. Recent data show that, with large differentiation across countries, the agricultural sector still determines the livelihood of 60% of Africa's population (675 million), provides jobs for 51% of the total economically active people (237 million) and contributes up to 40% of a country's gross domestic product^[9].

While above mentioned intensification approaches to overcoming Africa's constraints to growing agricultural productivity also reflect a donor learning curves from top-down, technocratic approaches of knowledge transfer schemes to more participatory, social-ecological problem definition and solution testing, the continent's problems

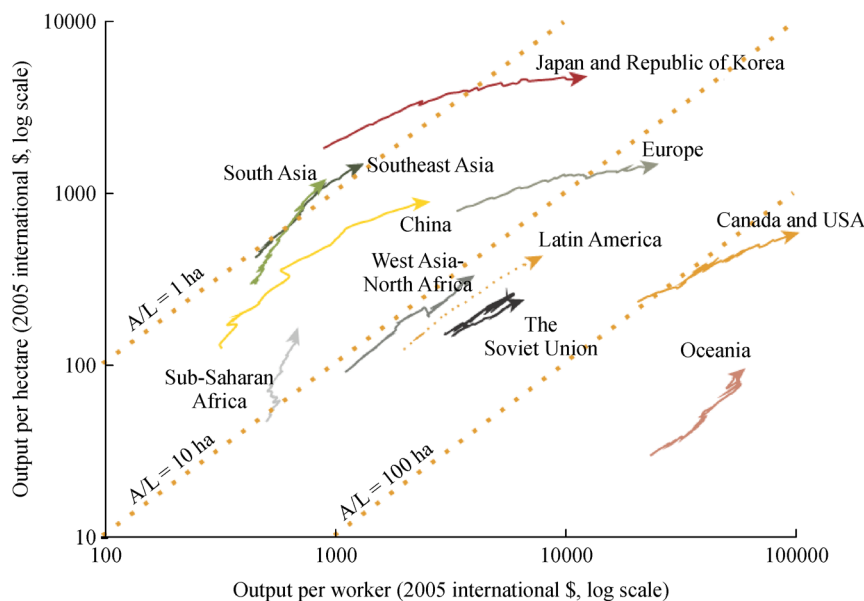


Fig. 1 Fifty-five-year (1961–2015) trends in agricultural land and labor productivity by region. Figure derived from FAOSTAT data^[5], the diagonal lines represent constant land/labor (A/L) ratios^[8].

are far more complex than described. The African countries' postcolonial position in international trade relations as predominantly producers of cheap raw materials and consumers of more elaborate industrial products, the world's lowest literacy rates, the difficult role of economically and socially largely outwards oriented elites, notorious tribal and ethnic conflicts, multilevel property rights of agricultural land and often weak governance provide a difficult amalgamate hampering the intensification of land use. The deleterious effects of this situation on agricultural productivity are further exacerbated by sub-Saharan Africa having the world's largest share of highly weathered, ancient soils (only matched Western Australia) very low in soil organic carbon, while experiencing strongly negative effects of global climate change on rainfall distribution over much of the continent's vast drylands. Increasing unpredictability of precipitation and lacking irrigation facilities^[10] will aggravate the deleterious effects of droughts and floods as further impediments to agricultural intensification throughout much of the continent.

2 Agricultural success stories

To our knowledge there are only few success stories of sustainable agricultural intensification in sub-Saharan Africa. Low agricultural investment and subsequent low production intensity reflect more low produce demand by consumer markets than lacking availability of effective technologies, high factor prices, or missing physical or technological infrastructure. Notably, all dryland countries in the Sudano-Sahelian belt stretching across the continent have a large producer community but only few centers of consumption that are economically weak and distant, with the wealthier consumers often preferring imported products. In the very limited secondary (industry) and tertiary (services) sectors in most of Africa there is too little demand for local agricultural products. This makes efforts toward higher agricultural productivity on these drylands futile. It is noteworthy that all of the following success stories of sustainable agricultural intensification are related to a dynamic development of consumer markets.

Land use in the Kano Close-Settled Zone in the Sahelian belt of northern Nigeria changed between 1960 and 1990 from traditional agro-pastoral systems based on slash-and-burn agriculture to an intensively managed agro-silvo-pastoral system. Thousands of private landholdings started to implement multiple cropping systems and intensive mixed crop-livestock husbandry with the use of manure compost and crop residue mulching to increase soil quality^[11]. The key driver of change toward enhanced land and labor productivity in Nigeria's politically unstable environment on sandy soils low in phosphorus was the growing demand for agricultural products in the sprawling

industrial and trading hub of Kano, with 3.6 million inhabitants^[12], the country's second largest city after Lagos.

A similarly widespread intensification at country level occurred in the Great Lakes Region of Rwanda after the civil war (1990–1994), when a stable government fostered the growth of a strong industrial and services sector in the nation's rapidly growing cities. Rising consumer demand for agricultural products in combination with a well-organized and partly subsidized input structure triggered a unique smallholder-based agricultural intensification which may nevertheless contribute to widening social injustice and new dependencies^[13].

A third and geographically widespread example is the development of irrigated hotspots of intensification. Hundreds of small fertile dryland depressions and river beds with easy access to water were used for intensive vegetable production. Similarly, strongly-market oriented urban and peri-urban agriculture (UPA) spread throughout sub-Saharan Africa over the last three decades. Mostly in the absence of agricultural extension, sectoral non-government organization activities and targeted credit programs, tens of thousands of small-scale farmer-gardeners, often recent immigrants from distant rural areas, established typically irrigated, multiple cropping systems and intensive animal husbandry. This intensification was based on easy access to inputs as well as booming consumer markets at low costs of entry^[14,15]. The advantages, but also limitations, of UPA systems are their focus on highly priced and rapidly perishable commodities, such as vegetables, fruits and dairy products, for which the weak transport infrastructure across the countries' hinterlands precludes rural production. Cooperative organization as well as traceability and product certification of UPA products are increasingly requested by urban consumers and allow countless families to reap the benefits of value chains, to secure their livelihoods while fostering multiple ecosystem services of agriculture in the urban and peri-urban space.

3 Concepts of sustainable agricultural intensification in sub-Saharan Africa

We claim that throughout sub-Saharan Africa indigenous theoretical concepts of sustainable agricultural intensification are either underdeveloped or lack practical application. This may be a result of postcolonial structures of political responsibilities, the complex coexistence of modern and traditional land use rights, the traditions of slash-and-burn agriculture prevailing until recently, and the still low level of formal education among rural populations in most parts of the continent. Low productivity of land and labor are typically not associated with local management, but regarded as a given and thus unchangeable, or

they are considered to be the responsibility of the state. Often, local systems of knowledge exchange among farmers and between farmers and other stakeholders are weakly developed^[16]. It is in this context where experiences from the Chinese agricultural transformation^[17] and its recent strive for sustainability^[18] could be of particular value. This may allow avoiding the traps arising from the previous technocratic views that traditional African agriculture consists largely of outdated practices and unskilled farmers.

4 China's agricultural development: an ambiguous model for agricultural intensification in sub-Saharan Africa

The social-ecological frameworks of land use in China and sub-Saharan Africa have some commonalities but also many differences which proscribe a direct transfer of development approaches. While for many centuries in both regions, production systems were smallholder-driven and subsistence-oriented, China has throughout its documented history always had major cities^[19] and thus developed rural-urban systems of exchange shaped by marketing opportunities. Both regions have large arid zones with major deserts and many agricultural areas are prone to sporadic droughts. However, compared to the granite-derived ancient Arenosols, Ultisols and Oxisols of sub-Saharan West and Central Africa with their low primary biomass production^[20], China's widespread alluvial or colluvial soils benefit from geologically recent loess and river deposits. This is even true for China's largest desert, the Taklamakan, whose vast oases flourish on the chemically fertile glacier deposits eroded from the nearby snow-covered Kunlun and Pamir Mountains^[21]. Under such conditions dryland agriculture becomes highly productive once irrigation systems are established.

Partly a consequence of powerful government structures that buffered people against the effects of famines by providing food aid in exchange for common labor, China's population has for a long time been more sedentary than African pastoralists and shifting-cultivators. The latter continue to suffer from the consequences of ancient tribal divides into a multitude of former kingdoms only loosely connected by trade, but most of history in rivalry for land, water, herds and human labor. These conflicts were deliberately fueled by competition for colonial power and arbitrarily drawn borders dividing ethnic groups. China's ancient hierarchical system of governance, instead, generated over centuries a constructed but powerful narrative of a common identity which became the basis for effective modern nation building.

Yet, despite these major differences, sustainable agricultural intensification of sub-Saharan African agriculture may benefit from elements of the Chinese experience of

agricultural innovation and recent efforts to boost "Agricultural Green Development"^[22]. Particularly valuable elements for testing the potential of agricultural transformation may be the fostering of effective agricultural input and output markets, the local small-scale production of simple machinery, seed and postharvest processing units including small dairies for milk processing, the use of the "Science and Technology Backyard" system for knowledge transfer^[23], and the strengthening of agricultural credit in combination with tenure reforms. This will require a long-term commitment to participatory development and policy reforms rather than reliance on the effectiveness of technical solution packages and on short-term hope for the development of new consumer markets for goods and services as it has quickly happened in modern China. What is needed instead is an approach that consistently tackles and fosters the much needed sustainable agricultural intensification in sub-Saharan Africa as a result of broad knowledge brokering in an on-going innovation and transition process^[24,25].

5 Conclusions

The widespread low intensity and often shifting nature of agro-pastoral land use in sub-Saharan Africa are the result of human adaptation to a multiple fabric of agroecological, historical, technical, economic, political and global production constraints rather than the consequence of technology failure or knowledge gaps. Therefore top-down efforts of commodity-oriented, agricultural innovation with the goal of sustainable intensification are unlikely to be successful. Fostering the availability of locally manageable (and reproducible) technologies and inputs seems more promising than generating new structures of dependency involving imports under the given, unbalanced terms of trade. Effective approaches of sustainable intensification will need to be participatory, educational, institution building, sensitive to gender and local values, and oriented toward the development of infrastructure linking market actors. Finally, sustainable agricultural intensification combining the goals of providing food sovereignty and enhanced resilience of agroecosystems must be based on investment in agriculture rather than on the predominant exploitation of the natural resource base. Such investments will ultimately depend upon the purchasing power and willingness-to-pay of consumers with off-farm employment who are interested in the benefits of local value-added crop and animal products.

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