Developing extension model for uptake of precision conservation agricultural practices in developing nations: learning from rice–wheat system of Africa and India

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We have learnt time and again that food supply shocks have resulted in food price spikes, instability, violence and even regime collapse. When the supply chain at the primary producers (farmers) level is functioning well, the success will ripple down the whole chain. In this review, we present our approach for the development of an extension model for the promotion of precision conservation agricultural practices (PCAPs) uptake among rice–wheat smallholder farming households, considering the demand as well as the prospect for developing and up-scaling rice–wheat production system in Africa. PCAPs are technologies and practices that are capable of helping farmers to apply right resources at the right place and, at the right time, using the right method. The combination of these technologies and practices can help in achieving optimum resource stewardship and resource conservation in the farmers' field. However, extension strategies and supports are needed to facilitate the adoption of these best practices at the farmers' level.

Keywords: Developing nations, extension strategies, rice–wheat system, smallholder farmers, sustainable agriculture.

THE challenge of ensuring global food security in the face of the changing climate and variability demands encouragement of agricultural innovation as well as adoption of proven technologies to face the unusual scenario. The world population has been estimated at 7.244 billion in 2015 and a projection of 9 billion, in 2050, of which the percentage share of the developing countries will be 97% (ref. 1). This means that we are expected to feed more than 9 billion people in 2050, of which about 805 million at present are hungry without enough food to live a healthy and active life, and 98.2% of undernourished people live in the developing nations[2,3]. With the present trend of changes in climatic conditions and their effect on agriculture, there is likelihood of drastic reduction in food production in the near future as well as impending food crises. How will the world produce food and other farm products for 9 billion people without adverse effects on the planet? How can we continue to produce under changing climates and growing competition for land and natural resources? The only choice is to enhance productivity on a sustainable basis from the limited natural resources at our disposal, without any adverse effect on the environment by maximizing the resource input use efficiency[4].

Farming households must be motivated to take up right farming practices. These initiatives must be backed up with maximum support towards enhancing their capacity to produce more for feeding the growing population. The need for agricultural extension support and strategies to achieve this target cannot be overemphasized considering the need to narrow down the widening gap between the actual and desired situation of food security by the application of science and technology. It is noteworthy to see the need for extension functionaries to develop strategies, innovative ideas as well as extension models towards promotion and uptake of novel practices and technologies by the farming communities. In order to see a desired change in achieving food security in the developing nations, especially Africa, the welfare and support for smallholder farming households must, therefore, be first in every agricultural development plan, programme and policy. The objective of this article is to present the prospect for driving African agricultural potential in developing rice–wheat system in the continent as well as modelling precision conservation agricultural practices (PCAPs) uptake as the right resource management practice, taking lessons from Indian rice and wheat system.

Current status of food production in Africa and India

With the current food crises in many African countries due to the inability of African agriculture to produce enough food to feed the growing population, there is a need to look from within to proffer solutions to the challenges limiting agricultural potential in Africa. Agriculture remains the major source of income and livelihood

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Table 1. Status of African and Indian agriculture

Indicator	Africa	India
Population (2015; billion)	1.1	1.25
Land area (million square miles)	11.7	1.3
Percentage of agricultural area/land	42.89	60.47
Percentage of arable land/agricultural area	19.36	87.51
Total area equipped for irrigation/agricultural area (%)	1.19	37.12
Permanent meadows and pastures/cover/agricultural area (%)	77.92	5.64
Agricultural machinery, tractors per 100 sq. km of arable land	63.4	102.2
Rural population/percentage of total population	66.5	67.25
Fertilizer consumption (kg/ha of arable land)	17.5	157.5
Total cereals production (million tonnes)	188	294

Source: ref. 66.

for Africans. Over 60% of Africans live in rural areas and rely on agriculture for their livelihoods, and women in Africa make at least half of the agricultural labour force[5,6]. Despite the natural and human resources available for agricultural development in many African countries, as a continent Africa has not been able to achieve food sufficiency (Table 1). Many African countries have opted for massive importation of food in order to meet their local demand, while few countries prone to war and insurgencies have greatly relied on food aid. FAO[7] reported that the net import of Sub-Saharan African countries was about US$ 35 billion in 2015 with a projection of about over US$ 110 billion by 2020, while the Near East and North Africa is rapidly becoming a net importing region. According to AFDB[8], there is impending challenge for Africa food security in the coming years considering the current negative net trade of agricultural products which is expected to rise in the absence of transformation (Figure 1).

On the other hand, India which is one of the South Asian countries sharing almost similar attributes with the African continent, especially in terms of population, agricultural resources as well as cultural diversity, has been able to transit from a net importing nation to food sufficiency as well as a net exporter of staple food. According to USDA[9], India has emerged as a major agricultural exporter, with exports climbing from just over US$ 5 billion in 2003 to a record of more than US$ 39 billion in 2013 (Figure 2).

Demand and prospect for scaling up rice–wheat production system in Africa

The need for developing rice–wheat production system in Africa cannot be overemphasized considering the change in consumer preference for staple and convenience food as well as a rise in the rate of urbanization[10,11]. Rice has become the single most important source of dietary energy in West Africa, and the third most important source for Africa as a whole[11]. For instance, the West African region imported about 8.47 million tonnes of rice in 2013, which is about 60% share of the total amount of rice imported into Africa with a cost of about US$ 4.47 billion[12]. About 30 million tonnes more rice will be needed in Africa by 2035, representing an increase of 130% in rice consumption from 2010, of which about one-third will be needed in Nigeria alone[13].

According to Kennedy *et al.*[14], assessment of percentage share of rice in dietary energy, protein and fat in the major rice-consuming countries in Africa revealed that it provides between 25% and 46% of dietary energy and between 27% and 43% of dietary protein (Table 2). There is a huge deficit in rice trade due to the rapidly growing consumption of rice than any other major staple food in the continent; Africa must work towards empowering the rice-farming households to establish a sustainable rice–wheat production system. Wheat, like rice consumption in all African countries, has been on a steady increase since the past two decades; the reason being changing consumer preference, growing population as well as strong urbanization trend which have led to a growing 'food gap' in all regions, largely met by imports[15]. African countries are the world's biggest wheat importers with more than 45 million tonnes in 2013 costing US$ 15 billion, equating to about a third of the continent's food imports[16]. With the rapidly growing urbanization in sub-Saharan Africa, wheat consumption is expected to grow by 38% by 2023 with imports already at 23 million tonnes in 2013 at a cost of US$ 7.5 billion (ref. 11). Africa can no longer afford to rely on the distorted global rice and wheat market, where major producing countries may restrict trade during periods of shortage in supply[11]. It is understandable that every shock in food supply has resulted in food price spikes, instability, violence and even regime collapse. A typical scenario of this is the case of 'food riots' of 2008 in some countries of Africa such as Burkina Faso, Cameroon, Côte d'Ivoire, Mauritania and Senegal, which led to violent protests, a testimony to the continent's vulnerability to international rice price volatility[11].

However, in view of the current widening gap in rice and wheat demand and supply, governments in Africa

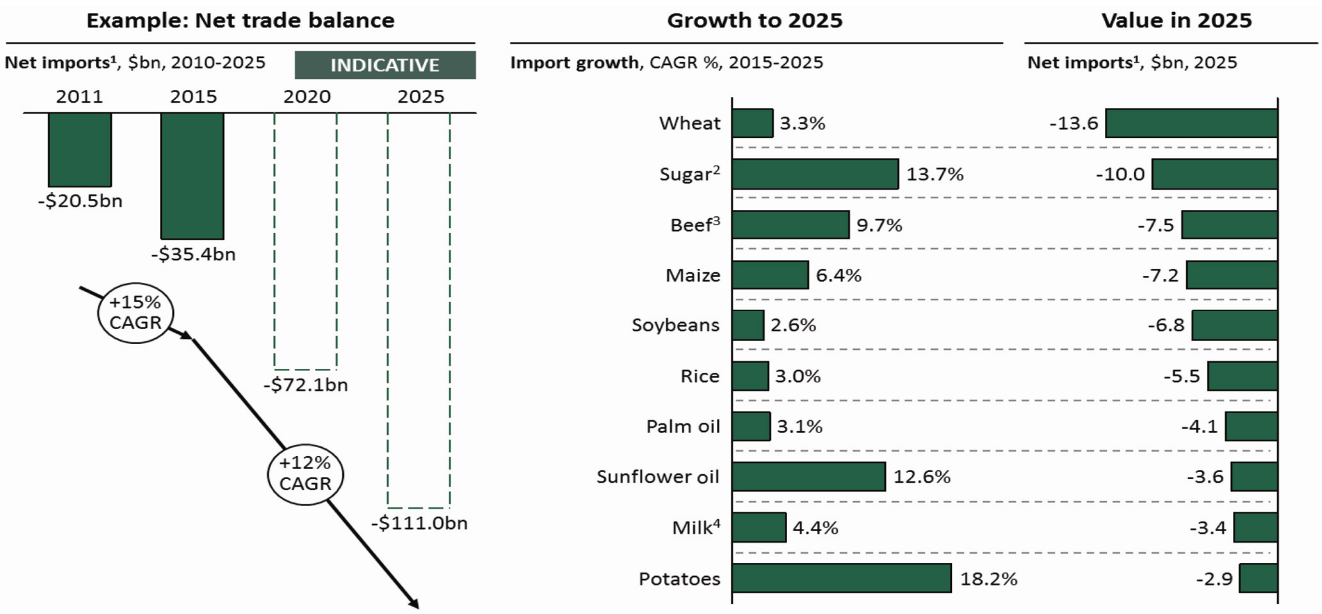

Figure 1. Significant increase in negative net trade of Africa in the absence of transformation. Source: IFPRI, IITA Dalberg analysis as cited in AFDB[8].

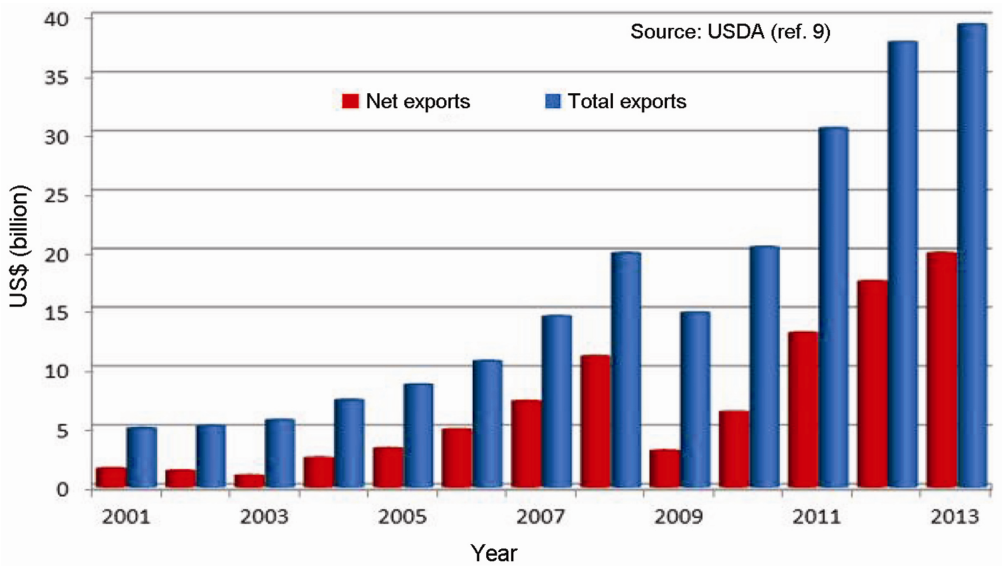

Figure 2. Net export of agricultural products from India. Source: ref. 9.

need to seriously explore opportunities and strategies to increase domestic production of rice and wheat through developing their capacity to produce the crops[17]. There is a great scope for the development and up-scaling of the rice–wheat system in Africa, especially when compared with India in terms of productivity (Table 3). For instance, Table 3 reveals that Africa has an opportunity to be self-sufficient in wheat production as the average yield is 2625.7 kg/ha, which is slightly close to the Indian average yield at 3145.7 kg/ha. Indian wheat sufficiency (95.8 million tonnes) can be attested to the large expanse of land under wheat cultivation of about 30.5 m ha compared to about 9.9 m ha in Africa. Also, Africa can achieve about 80 million tonnes of wheat with the opportunity to increase land under wheat cultivation to about 30 m ha from the current 9.9 m ha with the current yield of 2625.7 kg/ha, excluding other factors.

It is noteworthy to mention that wheat production presently covers about 10 m ha in Africa, of which the production data from FAOSTAT reveal that about 31 out of 54 countries have the capacity to produce, and are

Table 2. Percentage share of rice in dietary energy, protein and fat of major rice-consuming countries (Africa and South Asia)

Country	Supply (g/day)	Dietary energy (%)	Protein (%)	Fat (%)
Gambia	246.9	32.9	31.3	1.7
Senegal	186.7	29.2	28.7	1.6
Côte d'Ivoire	193.1	25.2	27.1	3.2
Guinea	185.4	31.3	31.6	4.7
Guinea-Bissau	258.0	40.9	39.2	2.2
Madagascar	251.5	46.6	43.6	11.8
Sierra Leone	258.4	44.1	33.5	2.9
India	207.9	30.9	24.1	3.6
Sri Lanka	255.3	38.4	37.0	2.7
Bangladesh	441.2	75.6	66.0	17.8
Nepal	262.3	38.5	29.4	7.2

Source: ref. 14.

Table 3. Area, production and yield of selected cereal crops in India and Africa (2014 data)

	India			Africa		
Crop	Area (ha)	Production (tonnes)	Yield (kg/ha)	Area (ha)	Production (tonnes)	Yield (kg/ha)
Wheat	30,470,000	95,850,000	3145.7	9,924,362	26,058,588	2625.7
Rice, paddy	43,855,000	157,200,000	3584.5	11,884,357	30,788,497	2590.7
Maize	9,258,000	23,670,000	2556.7	37,058,619	78,005,212	2104.9
Milliet	8,904,000	11,420,000	1282.6	19,727,439	12,409,333	629.0
Sorghum	5,820,000	5,390,000	926.1	29,355,124	29,192,947	994.5
Total		293,530,000			176,454,577	

Source: ref. 16.

producing about 26 million tonnes of wheat (Figure 4). Also, the mega-environmental and zonal climatic classification for the wheat system in Africa reveals four climatic zones and seven mega-environments with prospects of scaling up[18,19]. The mega-environments classification was based on the spatial analysis of critical agro-climatic variables such as rainfall, temperature, elevation, water management regime and soil constraints. Observation of these report shows that the constraints to up-scaling wheat production in the region can be managed if the Governments and stakeholders engage in a conscious effort towards maximum support for research and development in generating suitable technologies and promotion of best practices for wheat production system in the region (Tables 4 and 5; Figure 5).

In order to develop rice–wheat production system in Africa, concrete efforts must be taken by all stakeholders to learn from developing nations like India that have successfully developed this life-saving food system. Learning from the success and mistakes of the past will help us critically plan and build the future of African continent agricultural development programmes towards the first African green revolution. Among the efforts to be taken in Africa to achieve this target is to cultivate the attitude of making the farmers first in every agricultural development programme[7]. Over the years, smallholder rice farming households have been neglected by the policy makers, development agencies and their partners, especially in Africa, unlike in India where the government, policy makers, development institutions and scientists focus on the 'farmers' first philosophy and principle. This philosophy is to give maximum support to the welfare of farmers and building on this will enable the governments of African countries and developmental agencies to provide technical support and modern agricultural technology and tools to farmers. This includes changing from the traditional system of using crude and obsolete farm implements to modern smart-mechanization farming in Africa that is affordable to smallholder farming households[7,11].

Projected impact of climate change on food production system in Africa and India

There is no gainsaying the fact that climate is changing considering its evidence in different regions of the world. There is an increase in annual average surface temperature in many parts of the world; polar ice shields are melting and the sea is rising. In some regions extreme weather events and rainfall are becoming more common, whereas others are experiencing more extreme heat waves and droughts; these impacts are expected to intensify in the coming decades[19–28]. Food production system in

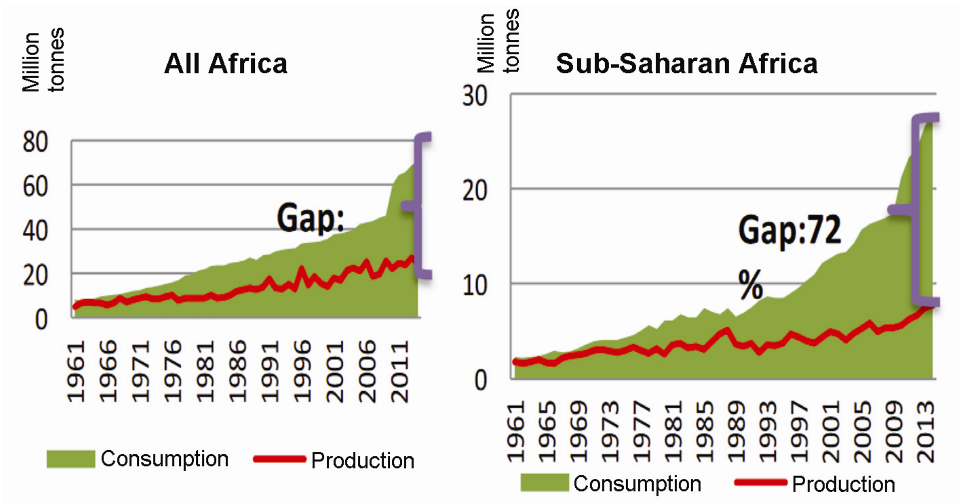

Figure 3. Widening gap between wheat production and consumption in Africa. Source: ref. 11.

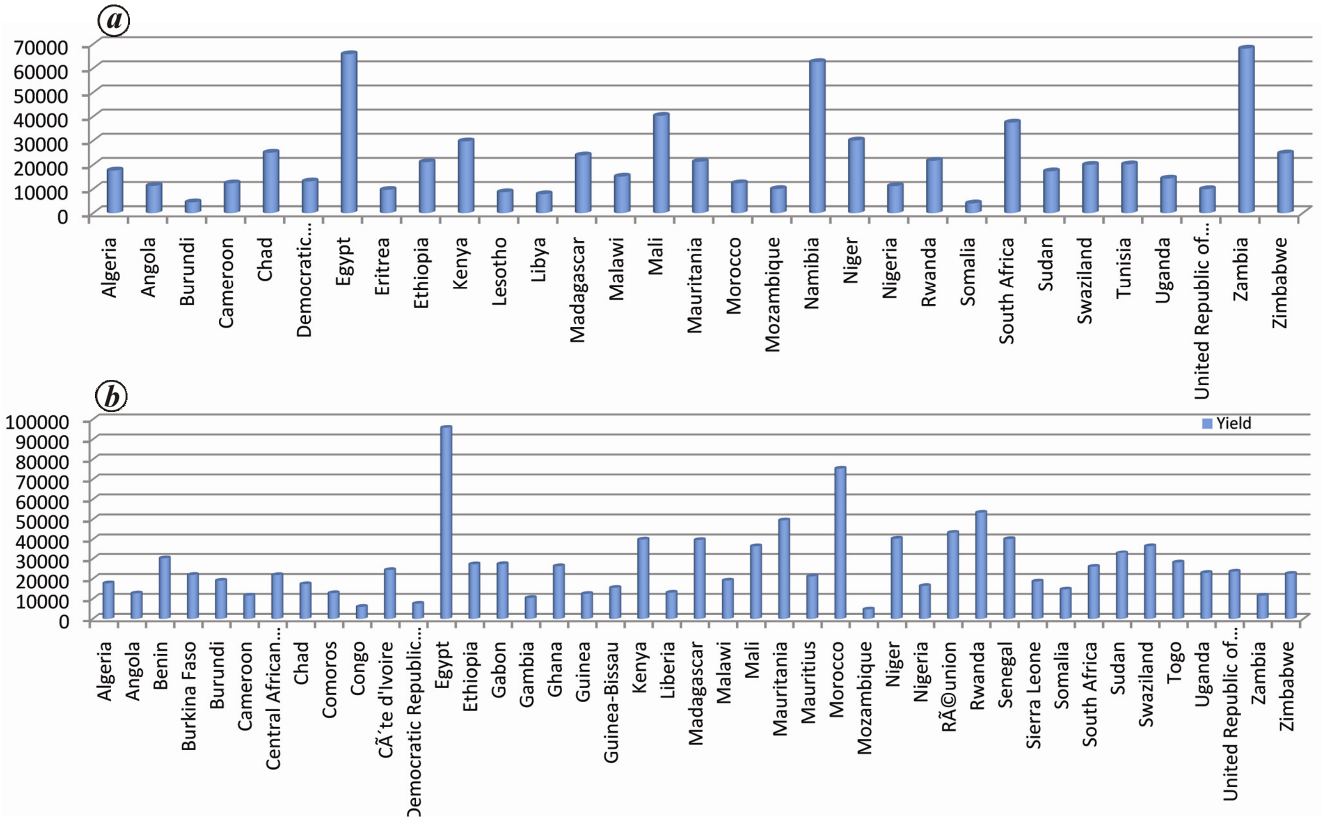

Figure 4. Country-wise wheat (***a***) and (***b***) rice yield (kg/ha) in Africa: scope for scaling-up production. Source: ref. 16.

developing countries is expected to be impacted by changing climate. The vulnerability of developing countries to the impact of changing climate is high, especially those with a large population that is largely dependent on agriculture for livelihood due to their low capacity to adapt easily. Like any other developing countries, South Asian countries and many countries in Africa with more than 58% of their population engaged in agriculture and allied fields are highly vulnerable to climate change impact[29,30]. According to Porter *et al.*[31], the estimated impacts of both historical and future climate change on cereal crop yields in different regions indicate that yield loss can be up to −35% for rice, −20% for wheat, −50% for sorghum, −13% for barley, and −60% for maize depending on the location, future climate scenarios and projected year.

Maheswari *et al.*[32] predicted that climate change impact on Indian agriculture will reduce yield by 4.5–9%,

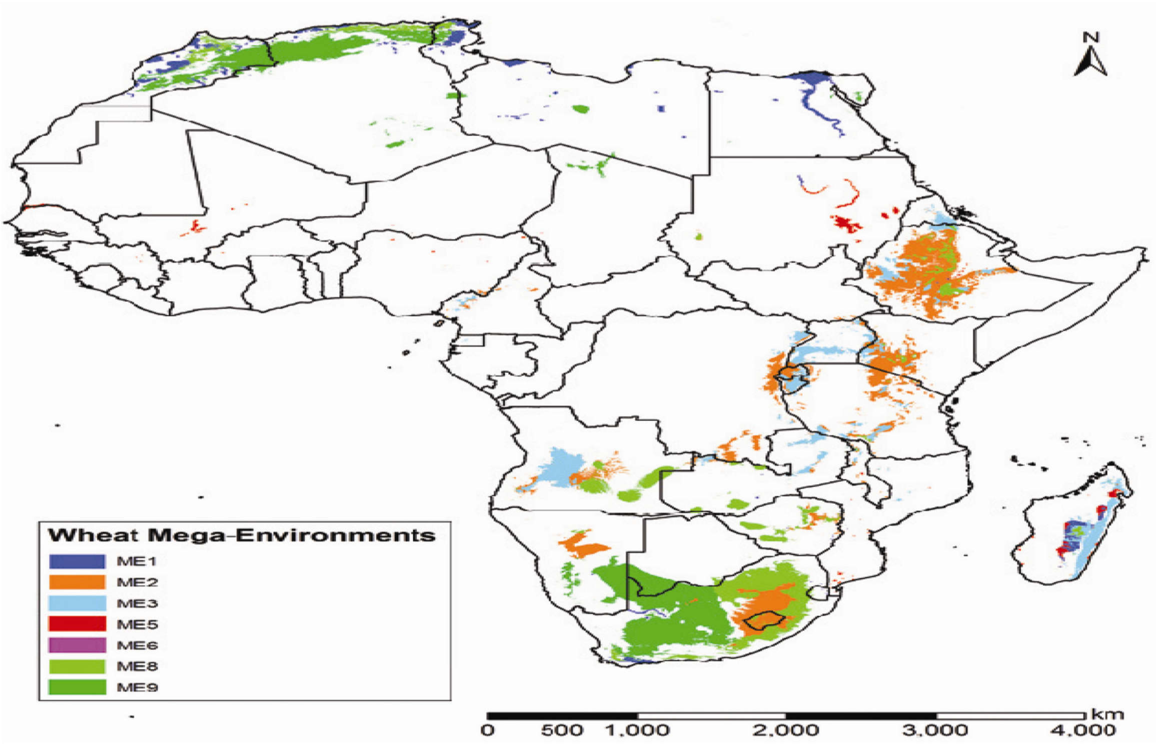

Figure 5. Wheat mega-environments in Africa. Source: Braun *et al.*[19]. ME 1, Low rainfall irrigated, coolest quarter (spring growth habit; three consecutive months) mean-minimum temperature >3°C and <11°C. ME 2, High rainfall in summer; wettest quarter (spring growth habit) mean minimum temperature >3°C and <16°C, wettest quarter (three consecutive wettest months) precipitation >250 mm; elevation 1400 m. ME 3, High rainfall and acid soil (pH < 5.2); spring climate as in ME 2 (spring growth habit). ME 5, Irrigated, low humidity; coolest quarter spring mean minimum temperature >11°C and <16°C. ME 6, Moderate rainfall/summer dominants (spring growth habit), coolest quarter mean minimum temperature < –13°C; warmest quarter mean minimum temperature >9°C. ME 8, >600 mm rainfall (facultative growth habit). ME 9, Low rainfall <400 mm, winter/spring rainfall dominant (facultative growth habit).

Table 4. Wheat production systems in selected countries

Country	Type 1: Dominant	Type II: Less dominant
Angola	Rainfed + hoe	
Burundi	Rainfed + hoe	
Ethiopia	Rainfed + ox	Rainfed + mechanized
Kenya	Rainfed + mechanized	
Malawi	Rainfed + hoe	Irrigated + mechanized
Mali	Irrigated + mechanized	
Nigeria	Irrigated + mechanized/hoe	Rainfed + hoe
South Africa	Irrigated + mechanized	Rainfed + mechanized
Sudan	Irrigated + mechanized	
Tanzania	Rainfed + mechanized	Rainfed + hoe
Uganda	Rainfed + hoe	
Zambia	Irrigated + mechanized	Rainfed + hoe/mechanized
Zimbabwe	Irrigated + mechanized	

Adapted from Tanner *et al.*[67].

which is roughly up to 1.5% of GDP per year within a medium term of 2010–39. The climate change impact on the productivity of rice in Punjab, India has shown that with all other climatic variables remaining constant, temperature increase of 1°C, 2°C and 3°C would reduce the grain yield of rice by 5.4%, 7.4% and 25.1% respectively[22]. Also, increased temperature would result in more water shortages and the increased demand for irrigation water, which in turn will result in about 20% net decline in rice yields in India[33]. An increase in winter temperature of 0.5°C would thereby translate into a 10% reduction in wheat production in the high-yield states of northern India[34].

In Africa, it has been projected that suitable areas for some staple crops such as common bean, maize, banana and finger millet will reduce significantly, about 30–50% across the continent[35]. Based on IPCC assumptions, a preliminary integrated assessment model adapted for

Table 5. Climatic zones for wheat production in selected countries of Africa

Country	Climatic zone	Constraints
Ethiopia, Kenya, Uganda, Rwanda, Burundi, Eastern DR Congo, Tanzania	Cool humid highlands	Weeds, acid soils, fungal diseases, tillage, waterlogging
Zambia, Zimbabwe, Malawi, South Africa, Madagascar	Mid-altitude, irrigated, cool, dry (winter season)	Fungal diseases, high production costs
Angola, Zambia, Malawi, Madagascar,	Mid-altitude, warm, humid (rainy season)	Acid soils and fungal diseases
Mali, Niger, Nigeria, Chad, Somalia, Sudan	Low-altitude, very hot, dry (irrigated)	Water availability, low temperature

Source: ref. 67.

the study predicts that there could be between 6% and 30% loss in GDP in Nigeria to climate change impacts by 2050, which could result in an estimated US$ 100–460 billion[36–38]. Across Africa, yields from rainfed agriculture could decline by as much as 50% and major cereals could decline by 20% by 2050. Beyond this, if global temperatures rise by more than about 1–3°C, declining conditions could be experienced over a much larger area[39–42].

Need for precision conservation agriculture in developing nations

Agricultural production in many of the developing nations is facing new challenges in recent times. The smallholder farmers are responsible for about 80% of food production in many of these countries, of which women accounts for about 43% of agricultural labour[43]. These groups are highly vulnerable to climate change with limited coping capacity[11,30,39–45]. In addition to this is the challenge of depleting water resources, soil degradation due to indiscriminate blanket application of fertilizers, fragmented land resources, declining underground water table, increasing scarcity and competing for resources such as water, land, and labour as well as socio-economical challenges. This has led to important food crops experiencing stagnancy, lower farm profit, making farming unattractive and unsustainable[46,47]. The current scenario of agricultural production in South Asian countries, especially in India is faced with similar challenges[48]. However, the African situation is not very different from the experience of India, except for the untapped agricultural resources in Africa, low level of mechanization, as well as lack of irrigation facilities and technical inputs.

However, the business-as-usual traditional/conventional cropping practices may not be able to meet the ever-growing demand for food with limited natural resources vis-à-vis the numerous challenges in developing nations. Hence the need for the development and deployment of appropriate sustainable crop production strategies under smallholder conditions to cope with the challenges of the 21st century. Precision conservation agriculture practices, however, can help sustain productivity and ensure food security as well as reducing the environmental impact of agricultural practices. Precision conservation agriculture (PCA) is one of the valuable options for climate-smart agriculture in the developing nations for cereal-based systems, especially in rice, wheat, maize, millet, sorghum, etc. PCA is defined as a set of spatial technologies and procedures linked to mapped variables directed to implement conservation management practices that take into account spatial and temporal variability of natural and agricultural systems[49]. PCA has its root in two concepts, namely, precision agriculture (PA) and conservation agriculture (CA). PCA is the integration of PA which is a management strategy to increase productivity and economic returns with a reduced impact on the environment 'through application of production inputs as needed, in the amounts needed and where needed for the most economic production'[50] and CA, 'a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment through minimum tillage, crop diversification as well permanent organic soil cover'[51], which is a holistic approach[47,52].

Precision conservation agricultural practices

PCAPs are technologies and practices, single or a combination of different precision farming technologies and conservation agronomic practices that can enable farmers to use the right input and the right place at the right time with the right method (4Rs). The basic principles involved in PCA practices include minimum tillage, crop diversification, precision application of nitrogen-based fertilizer to achieve higher nutrient efficiency both from organic and inorganic sources as well as the combination of improved fertility with improved seed for higher productivity[53,54]. Based on a review of the literature from rice–wheat production system of South Asian countries, we compiled and categorized PCAPs which are location-specific (Table 6)[55–61].

Although CA is not relatively new to farmers in Africa, PCA can help achieve the target of sufficient food production in a sustainable manner as agricultural

Table 6. Classification of precision conservation agricultural practices (PCAPs)

Category of documentation	PCAPs
Crop improvement practices	Improved, resilient, recommended crop varieties
Water management practices	Precision laser and levelling, alternate wetting and drying (AWD), direct seeded rice, crop diversification
Precision nutrient management practices	Leaf colour chart, handheld green seeker, nutrient expert decision support tools
Energy management practices	Conservation tillage/zero tillage, residue management, precision planters, indigenous precision planters
Risk management practices	Index-based insurance, ICT-enabled Agromet services, CIMMYT Agriplex

Source: Authors' compilation from a review of the literature.

transformation in Africa can be built on right practice from the start especially in cereals-based cropping systems such as rice–wheat, maize–beans, sorghum–beans, etc.[53]. It will also help bridge the yield gap in the African agricultural scenario when right practices are engaged. Jat *et al.*[48] hypothesized that PCA-based technological solutions dependent on small farm precision planting machinery and decision support tool (Nutrient Expert for maize) for precision nutrient management have the potential for bridging the yield gaps. According to AFDB[11], among the challenges of agricultural transformation in many African countries is poor mechanization, irrigation facilities, land degradation, biotic and abiotic stresses, changing climate and weak policy and institutional support. Giving maximum support for the uptake of PCAPs by smallholder farming households and its promotion in the African cereal-based system will facilitate transiting from current food insecurity to achieving food sufficiency.

Developing an extension model for uptake of PCAP by smallholder farmers

The innovative extension model (IEM) is a developmental strategy whereby proven technologies, methods and practices adopted in one location are introduced and replicated in another locality utilizing different extensions methods and approaches. According to Anandajayasekeram *et al.*[62], a model may be defined as a schematic description of a system or phenomenon that accounts for its known or inferred properties and may be used for further study of its characteristics. A model is something that can be copied because it is an extremely good example of its type, a standard or example for imitation or comparison or a representation, generally in miniature, to show the construction or appearance of something[63,64]. The approach to developing an innovative extension model for the adoption of PCAPs in rice–wheat system of Africa is to introduce PCA technologies and practices identified and documented, tested and proven in the Indian rice–wheat production system to the African countries (Tables 6 and 7). This can be piloted by introducing the technologies/practices, as well as refining them to suit the different local conditions. It can be done through on-farm testing refinement and demonstrations. The adaptable PCAPs can then be recommended for the National Agricultural Research System (NARS) of many African countries for upscale in rice–wheat system.

However, to achieve success in the PCAPs modelling, the smallholder rice–wheat farming households must be considered as the most important actors in the rice–wheat supply chain. Therefore, maximum engagement of the smallholder farming households is mandatory in a participatory mode, especially to build their confidence regarding the technologies/practices. During the piloting, prioritizing and assessing of PCAPs by smallholder farming households in rice–wheat system can facilitate their uptake at the farmers' field. This idea is built on the two principles of agricultural extension – the principle of participation and the principle of whole family approach. This may facilitate the future scalability of PCAPs, especially in Africa, towards the first African green revolution. The whole essence is to enhance the resilience of the smallholders rice producers to facilitate the sustainable supply of rice and wheat in Africa, which has become an important staple crop for food security in the continent. With PCAPs, smallholders rice–wheat farming households in Africa can achieve sustainable production and increase their income, enhance resilience and adaptation to climate change as well as reduce their contribution to the greenhouse gases emissions (GHGs) from rice–wheat production system (Table 7).

The farming system research with inculcation of PCAPs offers an opportunity to rice–wheat smallholder farming households to identify existing rice and wheat farming practices, prioritize and compare PCAPs for the possibility of upscaling suitable and adaptable options. Also, the novel PCAPs that have been prioritized by rice–wheat farming households in India from the research output have the possibility of scaling up in the African region. Also, the analysis for upscaling the PCA technologies and practices with 'gender lens' will enhance the potential contribution of individual rice and wheat smallholders farming households. This may, in turn, facilitate the acceptance of PCAPs by the whole family. Achieving food security in India is dependent on the success of smallholder farming households. When the primary actor

Table 7. Description of PCAPs and their perceived potentials towards climate-smart agriculture

PCAPs	Description	Food security	Climate risk management	Adaptation	Mitigation
Laser land levelling	A tractor-towed, laser-controlled device for precise flat surface for the purpose of equitable distribution of water in the field.	Medium potential	Medium potential	Medium potential	High potential
Green seeker	A handheld, easy-to-use crop sensor that is calibrated locally. It calculates the normalized difference vegetation index which indicated the crop health and nitrogen requirement. N-fertilizer can be easily optimized for increased crop yield and lower environmental footprint.	High potential	–	Reasonable potential	High potential
Leaf colour chart	A visual chart used for measuring the greenness of the leaves to quantify the nitrogen to be applied to rice and wheat field for maximum productivity.	High potential	–	Reasonable potential	High potential
Nutrient expert-decision support tool	An interactive software for site-specific nutrient management tool for precision application of fertilizer	High potential	–	Reasonable potential	High potential
Crop diversification	Addition of new crops or cropping systems to increase the crop portfolio so that farmers are not dependent on a single crop	High potential	High potential	Reasonable potential	Reasonable potential
Residual management/ mulching	A system of maintaining a protective cover of vegetative residue on the soil surface.	Medium potential	Medium potential	Medium potential	High potential
Zero tillage	A way of growing crops with no disturbance to the soil through tillage.	Medium potential	High potential	Reasonable potential	–
Tensiometer (alternative wetting and drying)	A monitoring instrument that facilitates farmers' decision of when to irrigate rice field during alternate flooding and drying practices.	Medium potential	Reasonable potential	High potential	High potential

Adapted from ref. 68.

in the supply chain is functioning well, the success will trickle down the chain.

Another factor for success of any agricultural technology/practice modelling is the high demand for institutional support for smallholder farming households. Over the years, smallholder rice and wheat farming households have been neglected by the policy makers, development agencies and their partners in many African countries, unlike in India where the government, policy makers and scientists focus on the farmer FIRST kind of programme in support of these important actors in the supply value chain. This programme has been recently launched by the Indian Council of Agricultural Research. It is an innovative agricultural programme that supports for farmers' farm innovation resource science and technology. Hence, the need for the governments of African nations to come forward with 'farmers first' initiatives. This will benefit farming communities and facilitate the process of changing the status of the continent from net importer to food-sufficient nations.

Developing nations, especially many African countries have the potential to produce their own food sustainably if the stakeholders in food production system will engage in right farming practices. The uptake of PCAPs by smallholder farming households is a valuable option for climate-smart agriculture in the developing countries, especially in the cereal-based production system. According to FAO[55], climate-smart agriculture is defined as an approach to achieve Sustainable Development Goals through integration of the three dimensions of sustainable development (economic, social and environmental) with the focus to address jointly food security and climate challenges. These three pillars of climate-smart agriculture are achievable with the uptake of right farming practices.

Many empirical studies conducted on PA and PCA in the developing nations, especially in cereal-based production system of south Asia shown that implementation of these practices increases crop yield, farm income and input use efficiency and helps farmers adapt and mitigate the impact of changing climate[30,52,56–61]. However, development of extension strategies and support to farmers in order to facilitate adoption of any technologies cannot be overemphasized. It is noteworthy to mention that agricultural extension services over the years have been behind several successful agricultural development strategies.

However, despite the benefits of PCAPs in rice–wheat production system, especially as revealed by farmers' practices in the Indo-Gangetic Plain, there are no concrete studies or developmental projects on the prioritization, development, refinement and assessment of PCAP technologies and practices in rice–wheat production system of many African countries. This is unacceptable considering the fact that rice and wheat have become important cereal crops for food security in Africa[17]. To tackle the food security challenge of achieving self-sufficiency in Africa, many African countries responded with the national rice development strategy with the aim of achieving self-sufficiency in rice by 2018. How can Africa achieve this ambitious goal? How will climate change impact smallholder rice farming households and how can the resilience of smallholder rice and wheat farmers be increased? This calls for modelling PCAPs by introducing/promoting, prioritizing, refining and upscaling the right technologies and practices as an option for CSA in rice–wheat production system in Africa.

Conclusion

There is hope for Africa in the nearest future as all stakeholders take up the challenge for right practices and maximum support for smallholder farming households. Africa has 65% of all the arable land left in the world to meet the food needs of 9 billion people on the planet by 2050 (ref. 65). This huge untapped potential can be turned to a viable productive one for food security in Africa and beyond. Adoption of right practices in the agricultural production system as well as 'farmers first' policies will go a long way in achieving the target of feeding the growing population of the developing nations in a sustainable manner. PCAP is profitable and can help bridge the yield gap; increase incomes as well facilitate the capacity of smallholder farming households to adapt and mitigate climate change. The need for extension strategies and support cannot be undermined. The smallholder farming households, especially in rice–wheat production system in Africa require adequate information, input support, awareness as well as incentives and technical knowhow for the uptake of adaptable PCAPs in rice–wheat production system.

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