Rural21

The International Journal for Rural Development

No. 2/2015
Volume 49
ISSN 1866-8011
D 20506 F

Rural mechanisation

Photo: T. Daum

www.rural21.com

Editorial

Dear Reader,

It's easy to find arguments in favour of raising the degree of farm mechanisation. The performance and efficiency of farming activities is enhanced. People's living conditions improve, for the drudgery that also makes farming so unattractive for young people is no longer necessary. Standardised, optimised processes along the entire value chain raise the quality of primary and processed goods; harvest and post-harvest losses are reduced. Not only can the higher-value products fetch better prices, but they also allow for potential new markets. Furthermore, a services sector develops around production, marketing and the use and repair of technical equipment that creates jobs, boosting the economic power of rural areas. And last but not least, coupled with higher purchasing power, the quality and volume of food produced also improves the food situation of the population – a process that has been characteristic of many industrialised countries.

However, when it comes to transferring these positive developments to other regions, things don't always work out the way they should – this is nothing new either. Even the finest technology will be of no use if it is not applied or not properly employed – perhaps because its operation or maintenance is too complicated, because it doesn't fit into the societal context or sections of society – often women – are barred from using it, because farmers do not benefit from it or simply because they lack the (financial) resources and no concepts have been drawn up for the sustainable use of the new technology. The state-led mechanisation programmes of the 1960s and 1970s in various countries in sub-Saharan Africa may serve as an example.

As is so often the case, what counts for the pros and cons of mechanisation is how things are done. You will soon notice that our authors clearly belong to the advocates of mechanisation, although they do consider what has happened in the past, draw conclusions from mistakes that have been made and point to shortcomings in today's concepts. In the first part of our focus (p. 6–22), we present the way things are at the moment and current trends. Our authors show why and how the individual regions throughout the world have developed differently in terms of mechanisation and which concepts are really forward-looking, i.e. sustainable with a view to climate change and scarce natural resources, and are above all also suitable for smallholders (p. 6–9 and 10–13). Here, it becomes apparent again and again that progress is particularly slow, if not stagnating, in sub-Saharan Africa. This applies both to draft animals, which have often been employed as an intermediate technology in many regions of the world (p. 14–15) and to engine power, even if its use is strongly promoted by governments (p. 20–22). Our authors take the example of the potato sector in Kenya to demonstrate the prospects for mechanisation from the angle of German development cooperation and the potential role of public-private partnerships (p. 16–19).

In the second part of our focus, we present best practices and promising projects – at very different levels of the value chain and with very different levels of technology (p. 23–31). What all innovations have in common is that they not only improve the work routines in the smallholdings but are also less of a strain on the environment – with less water being needed, fewer pesticides being used or a lower accumulation of plastic waste. And last but not least, our example from India demonstrates how worthwhile it can be to opt for the innovative potential and the knowledge of the farmers themselves instead of for technology transfer from outside (p. 30–31).

Nearly all of the articles also refer at least implicitly to the need for climate-smart agriculture. But what exactly does adaptation to climate change mean for agriculture and for the future of rural communities, and what are the implications for development work? A case is made for abandoning conventional approaches on pages 32–33.

It is undisputed that the development of safety nets has to be among the measures to adapt to climate change. In West Africa, the tradition of cereal banks is being reconsidered. Our author has examined why these arrangements work in some villages and fail in others in The Gambia (p. 34–36).

The aim of many development cooperation projects is to facilitate smallholders' market participation. The Market Systems Development approach tries to identify the constraints within a value chain and to recognise the reasons why a market is not functioning properly. Quite successfully, as our example from Tanzania shows (p. 37–40).

Our last contribution addresses a topic that may no longer be dominating the news but continues to determine the lives of the people affected: the Ebola epidemic. While daily life in the regions hit has largely returned to normal, this is by no means the case for the food situation of the population (p. 41–43).

We wish you inspiring reading!

Silvia Richter

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"Our world, our dignity, our future"

The European Development Days were held in Brussels/Belgium in early June, under the motto "Our world, our dignity, our future". They formed the core event of the European Year for Development, declared by the European Commission for 2015 under the same motto. In more than 130 sessions, around 5,000 participants discussed burning development issues arising from a wide spectrum of cross-sector topics ranging from citizenship, inclusion, gender and human rights through food, education, health, climate and energy to financing, growth, jobs, migration and trade.

"Move up or move out"

Alone 13 of the sessions at the meeting centred on the topic of food and nutrition security. More than once, the key role that small-scale and family farming has in this context was stressed. After all, today's small-scale farming concerns some 2.8 billion people and accounts for 30 to 60 per cent of the world's least developed countries' gross domestic product. The participants in the 'Small-scale farming and sustainable food systems' session emphasised that by supporting this model, millions of families could live decently from their work.

"Smallholders should be treated as a business, and we need a strategy to either move them up or move them out," said Shenggen Fan, Director General of the International Food Policy Research Institute (IFPRI) in Washington. It was not fair to keep them on farms that could not sustain them adequately. In addition, there was the danger of their perpetuating the cycle of food insecurity – poverty – unsustainable production, because, for example, they were forced to manage already degraded land. At policy level, unsustainable subsidies such as those for water and fertilisers should be removed, and these resources should instead be used to help small farmers to produce more – and especially more nutritious – food and to gain access to markets.

These demands were supported by Adriana Opromolla, International Advocacy Officer at Caritas Internationalis. Opromolla presented the results of an international survey on food security among its 160 members showing that the principal causes of food insecurity are a lack of resources such as land and seed, the absence of finance/loans, poor access to markets, low agricultural productivity and the impact of climate change. However, the report also demonstrates that there are significant differences from one continent to another. Whereas in sub-Saharan Africa, low productivity and climate change are key problems, in Asia, the priority is a lack of access to resources and a lack of governance. In Latin America and the Caribbean, the main problems are seen as food prices, speculation and a lack of infrastructure. And in the Middle East, the key issues are conflict and the lack of clean water.

Strengthening cooperatives

A further option to empower smallholders is to help them get organised. This is being carried out, for example, by Caritas in Ethiopia, as Abdelghani Sourji, senior consultant for agriculture and rural development, explained. Although the country has around 30,000 agricultural cooperatives, as the state has pushed the farmers to create cooperatives at a very rapid pace, many of them lack infrastructure and resources. Caritas is helping them not only to build storage facilities to buy and sell grain and to store inputs, but also to build the infrastructure for cooperative unions. The unions are providing services for their members such as improved seeds, technical services and loans/credit services. The cooperatives are run as businesses that have to make a profit and sustain themselves. Sourij also reported that Caritas had helped set up a guarantee fund in which the risk was shared 50-50 with a cooperative bank. In addition, the organisation launched an asset building programme to help the poorest smallholders buy small ruminants and seed. Owing to droughts occurring every three to four years, many of the farmers in the project region are forced to sell their assets, making them dependent on food aid.

Adriana Opromolla

Photos: European Commission

Produce more with less

"We must invest more in nutrition security," stressed Jean-Pierre Halkin, Head of the Rural Development, Food and Nutrition Security Unit at the European Commission's Directorate-General for Development and Cooperation. "We must also make agriculture and the food system more sustainable by using fewer resources." By 2050, developing countries would need twice as much food as today. Here, priority had to be given to producing more nutritious food and using less water and other inputs. There was no single solution to this. The participants in the session 'Feeding the planet together', agreed that improved technology, better financing, improved education, easier market access and good governance all had to go into the mix.

"We don't need a green revolution in Africa. It was conceived at a point when we had cheap energy," maintained Patrick Caron, Director General for Research and Strategy of the French Agricultural Research Centre for International Development (CIRAD). "The context is different now, and the solutions that worked yesterday won't work today or tomorrow." Caron called for a global revolution in agriculture, a technologically smart revolution that

would contribute to development and was sustainable. The panellists stated that the need for productivity to rise was undisputed. At the same time, the problem of wastage had to be tackled, given that a third of all food world-wide was lost. Measures were necessary not only to increase food availability, but also to protect the environment. A vote in the audience showed that a majority felt that addressing climate change and focusing on sustainable development offered the best routes to achieving food security. While better technology would clearly be important, the panel was less certain about greater mechanisation in sub-Saharan Africa, where many farms were too small for tractors to be of much use. But greater mechanisation, together with more technology, could help to attract young people to farming; 350 million young people were joining the labour force in Africa over the coming 15 years, and other sectors were not able to provide the jobs.

Strong commitment to eliminate undernutrition

With 160 million children stunted and millions more suffering from micronutrient deficiencies, global malnutrition remains an urgent development challenge. Malnutrition contributes to half of child deaths world-wide. But until now, only one per cent of Official Development Assistance has gone to addressing the problem, as Melinda Gates, Founder and co-chair of the Bill and Melinda Gates Foundation, criticised. In the session "Joining forces to make undernutrition history", several initiatives were introduced. Germany's Parliamentary State Secretary to the Development Minister, Thomas Silberhorn, presented the 'One World – No Hunger' initiative which was launched by the German Government last year and is backed with 1.4 billion euros. Silberhorn explained that the programme had two main goals: to address hunger and malnutrition now by focusing on women and nursing mothers, and to ensure that future generations had food by working on value chains in food production from the farm to the table.

Nigeria ranks second in the world in both deaths due to malnourishment and stunted people. With its endowment of 1.25 billion US dollars, Nigeria's Dangote Foundation was making inroads in the battle against malnutrition, Zourera Youssoufou, Chief Executive Officer of the Foundation, explained. Youssoufou cited the example of the Foundation's nutrition programme, which feeds 10,000 people three times a day, 365 days a year. Also, an economic empowerment programme helps people find ways to earn better incomes. Youssoufou argued that women's empowerment had to be a key element of the drive as they were important players in their roles as farmers, consumers and mothers. This initiative would include encouraging mothers to breast feed, returning to what had always been the traditional method of feeding infants. The Foundation was also working to encourage more investment in the area by the African private sector and local philanthropists. "The reality is that most of our problems have to be solved by ourselves in Africa", Youssoufou maintained. Here too, several speakers noted that nutrition could not be tackled by addressing any single cause. Linkages had to be made among a range of development issues, including agriculture, health, water and sanitation, and education.

Matthias Ruete


Zourera Youssoufou

Migration – a driver for development

Just three weeks ahead of the European Development Days, the EC had launched the European Agenda on Migration. One of the central themes it contained was recognising migration as a development enabler, noted Matthias Ruete, Director General of the European Commission's Directorate General for Migration and Home Affairs. By addressing political, economic and social instability, development cooperation helped to ensure that migration was "a choice rather than a necessity", said Ruete in the session, 'Making migration a driver of development'. "Migration is development. Development is migration. They go hand in hand," maintained Dilip Ratha, Head of the World Bank's Global Knowledge Partnership on Migration and Development. Migrants' remittances were a major source of revenue and development for their home countries, he emphasised. So were the savings built up by the diaspora and their massive support for philanthropic projects. Officially recorded remittance flows to developing countries are estimated at 382 billion euros for 2014, which represents three times the volume of official aid flows to developing countries.

Laura Thompson, Deputy Director-General of the International Organization for Migration (IOM) reminded the meeting that, as well as being workers, migrants were potential employers, entrepreneurs and investors. More emphasis had to be given to protecting migrants' human and labour rights and their health, she said. The panellists acknowledged that these demands had also been taken up in the Sustainable Development Goals (SDGs). Notably, migrants are mentioned in the SDGs on protecting labour rights, facilitating orderly, safe migration, and reducing the transaction costs on migrants' remittances to less than three per cent by 2030. ***Silvia Richter***

A woman entrepreneur in Zambia attending a four-wheel tractor (4WT) operator and agribusiness training course.
Photo: B. G. Sims

Rural mechanisation – where are we now, and where should we be going?

The world's smallholder farmers will have to bear the brunt of the need to increase food production for a growing world population. At the same time, the rural population is expected to decline substantially in the coming decades. The only way to master this challenge is with the aid of mechanisation – which simultaneously has to be environmentally compatible, climate-smart, adapted to local conditions and affordable. Can this work?

Mechanisation is a crucial input into agricultural crop production and one that has historically been neglected in the context of developing country agriculture. Increasing the power supply to agriculture means that more tasks can be completed at the right time and greater areas can be farmed to produce greater quantities of crops. Innovation in mechanisation also means that new technologies can be employed to produce crops more efficiently by using less power. The prime example of this approach is reduced and no-till farming as traditional soil preparation practices, using ploughs of various types, are extremely energy demanding (and damaging to agricultural soils). The urgency of addressing the issue of farm power paucity is brought into sharp focus by the projections of world population and rural-urban migration. The global population (currently 7.31 billion) is on track to reach nine billion by 2050 and exceed eleven billion by the end of the century. The world's 500 million smallholder farms currently produce around 80 per cent of our food, and it is they who will have to bear the brunt of the need to increase food production by over 60 per cent by 2050 compared to 2007 levels. Currently, many of these smallholder farms have limited access to production inputs, especially mechanisation, and therefore achieve low levels of productivity. At the same time the rural population is expected to decline as people, especially the young and fit, migrate to urban centres in search of a life of less drudgery than can be offered by agriculture. Today, 50 per cent of the population in developing countries live in the rural sector, and this is projected to fall to 30 per cent by 2050. Given the current importance of human muscles in smallholder agriculture, the power limitation implications are grave (see box on page 7).

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Natural resources and climate change

Increasing food production whilst conserving the planet's natural resource base will not be a simple task. A second Green Revolution like the first one, which was able to more than double global food production in the second half of the last century, is very unlikely today. Rates of growth in the yields of the world's major food cereals (wheat, rice and maize) are now falling, and this is due in no small part to the degradation of agricultural land. Increase in food production via a process of sustainable intensification will, necessarily, require the implementation of more natural resource-friendly production methods, for example reduced- and no-till farming as part of a conser-

vation agriculture (CA) paradigm, and this will require a major diffusion of novel mechanisation technology.

Anthropogenic greenhouse gas (GHG) emissions are also creating havoc with the world's climate according to the UN's Intergovernmental Panel on Climate Change. GHG emissions are projected to grow in all sectors, except for net CO_2 emissions in the agriculture and forestry sectors. This is specifically due to carbon (C) sequestration in forestry and C sinks in agricultural soils. Clearly agricultural soils can only be C sinks if they are not eroding or having their C oxidised by tillage – so that CA has an important part to play in this process (see Box on page 9).

The difficulties

It seems that the case for increasing farm power and improving mechanisation options is quite powerful. However advances in some regions, especially in sub-Saharan Africa (SSA), are not as rapid as they need to be to avoid severe food security crises in the near future. State-run tractor mechanisation hire schemes have largely failed wherever they have been introduced, and now is the time to consider alternative solutions. One option would be to encourage the adoption of low-power (up to 25 hp) tractors of both two- and four-wheel configurations. Such power units are now in abundant supply both from China and India at accessible prices. However, in the case of SSA, even modest investments in farm power and machinery may be beyond the reach of most smallholder producers as they are, by definition resource poor. Capital has a high opportunity cost and there will usually be strong competing demands for investment elsewhere.

Another major constraint to motorised mechanisation adoption, at least in the early stages, is underdeveloped infrastructure. Engines need reliable and competent back-up services such as the availability of clean fuel, mechanics and replacement parts. Access to markets both for essential complementary inputs and for transporting agricultural produce to processors and markets requires good, or at least functional, rural road infrastructure, but this is frequently undeveloped or, if available, inadequately maintained.

How to improve smallholders' access to mechanisation?

For all the reasons discussed above, it would seem that an attractive option to improve access by smallholders to mechanisation is to offer the service from well-equipped and well-trained local service providers. Entrepreneurs willing to provide environmentally appropriate mechanisation services should be nurtured and offered the relevant training to become skilled machinery operators and effective and profitable business people. This may often require specialist training, which is where both the public sector and international donors can play a key role. The technical skills required will include machinery operation, maintenance and servicing as well as a detailed knowledge of calibration of equipment such as planters and sprayers. Business skills that are needed will include market appraisal, machinery costing and charge rates, cash flow control, partial budgeting and record keeping.

Subsidies can often help to kick-start interest in, and adoption of, innovations. Smart subsidies support the development of demand and participation in input markets using vouchers and grants. Smart subsidies should also be employed to steer producers towards the adoption of environmentally friendly innovations (in contrast to perverse subsidies encouraging natural resource use and biodiversity depletion, which should be phased out). For example, the use of e-vouchers promotes farmer-driven and market-friendly recovery and development; the system can be used to stimulate the demand for mechanisation services from newly equipped service-provision entrepreneurs. A successful e-voucher scheme in Zambia, implemented by FAO, has underlined the efficacy of this strategy.

Power sources in agriculture

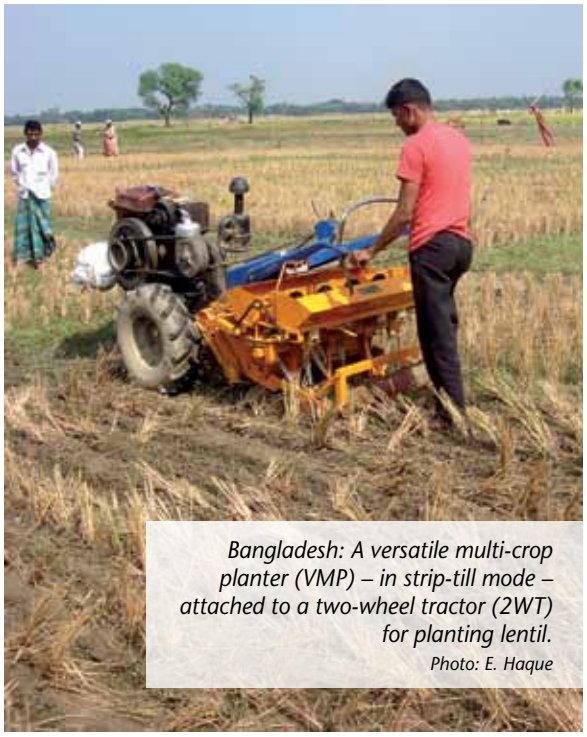
The power sources for developing country agriculture are human and draught animal muscles, internal combustion engines and electric motors. The use of the different sources varies across regions (see table). Generally engine power is on the increase, whilst draught animals are tending to decline in numbers, although locally, they can still be very important. The move away from muscle power towards tractors and engines for agricultural production, pumping and post-harvest operations is much more rapid in Asia and Latin America. Draught animal numbers in India and China are falling dramatically (from a peak of over 100 million in both countries) and are being replaced with 4-wheel tractor power, whereas in Bangladesh, draught animals have been replaced by 2-wheel tractors and 80 per cent of land preparation is now carried out with them.

Sources of power for land preparation (% of total)

	Human muscle power	Draught animal power	Engine power
Sub-Saharan Africa	65	25	10
East Asia	40	40	20
South Asia	30	30	40
Latin America and the Caribbean	25	25	50

Source: FAO Agricultural and Food Engineering Technical Report No 3, 2006, p. 6.

Another, related, approach is the use of 'cash transfers' to poor households. This enables poor families to better cover their basic needs but also allows them to use this income to invest in equipment needed for production (i.e. mechanisation equipment) and hence boost the local economies and local supply chains. In some countries, pilot projects are on-going through which farmers receive payment for no-till agriculture for increasing the carbon sink capacity of farmland. This 'payment for environmental services (PES)' provides new income streams for farmers who apply mechanisation innovations, in this case no-till and CA, and so catalyse the demand for mechanisation innovations. One such project, FAO's Mitigation of Climate Change in Agriculture in Tanzania (MICCA, see Box on page 9) has shown that PES can increase CA adoption and result in higher maize yields with lower GHG emissions.



Bangladesh: A versatile multi-crop planter (VMP) – in strip-till mode – attached to a two-wheel tractor (2WT) for planting lentil.
Photo: E. Haque

Creating demand for innovative mechanisation options may sometimes be a useful and necessary contribution to the development of infrastructure and market linkages. Scaling out CA, for example, can benefit from the involvement of a range of catalytic organisations, both from the public and international donor sectors, as well as from the private sector. This can take the form of market creation and assurance through contract farming and purchasing guarantees, including partnering with the public sector extension programmes to encourage the use of environmentally friendly practices. The United Nations' World Food Programme (WFP) has embarked on such an approach through its Purchase for Progress (P4P) programme in Zambia.

In the recent past, many efforts have been made by donors and development agencies to initiate activities at pilot scale that introduce the principles of CA and with it innovations in mechanisation technologies fitting the sustainability paradigm, often through farmer-driven methodologies and extension approaches such as Farmer Field Schools or Lead Farmers. Such pilot projects have provided the necessary inputs, including equipment (principally no-till planters, animal or tractor drawn rippers and sub-soilers, and equipment for mechanical and chemical weed and cover-crop management). The most effective of these tools, the no-till planters, were hardly available in SSA and needed to be imported (especially from Brazil). As a result, there was initially an artificial, donor-driven supply of these equipment innovations. The demand is gradually being satisfied by private-sector importation and local manufacture of the simpler implements.

Efforts at creating demand for climate-smart and environmentally friendly agricultural innovations (and their mechanisation) should be on-going. Although the public sector has a major role to play (for example in funding research, organising field days and improving extension efforts), the private sector should also be encouraged to participate through demonstration plots, out-grower technical support, machinery fairs and the formation and consolidation of CA farmer mutual support groups.

The future: a holistic approach to sustainable intensification

To enable the world to feed itself sustainably in a scenario of rising populations, growing rural-urban migration, ever more serious natural resource degradation (especially soils) and the increasingly negative impacts of the effects of climate change, the emphasis will have to be put more firmly on models which produce more, and more sustainably, whilst conserving the resources vital to allow agriculture, and indeed the human race, to prosper. This paradigm has been called sustainable crop production intensification (SCPI) and it entails the employment of CA production systems with their emphasis on no-, or dramatically reduced tillage, permanent organic soil cover, the use and integration of leguminous cover crops, and the proliferation of crop rotations and associations (especially between cereals and legumes). Agroforestry is another component of SCPI whereby trees are introduced into the agricultural landscape for production and resource protection. In this scenario, the use of fertiliser trees, such as *Faidherbia*, is particularly relevant. This type of climate-smart agriculture, which sequesters carbon in soil and biomass and eliminates soil erosion whilst fostering the production of healthy, fertile soils, is an imperative way ahead for the world's farmers, and it requires specialised mechanisation solutions and schemes for monitoring their impact (including enhancing potential carbon sinks) to enable farmers to access PES income and further encourage and promote the use of sustainable mechanisation inputs.

As far as power sources for agriculture, especially smallholder agriculture, are concerned, there is clearly a need to reduce the drudgery associated with the over-dependence on human muscle power. The drudgery of smallholder agriculture is a major factor in driving able-bodied, fit people into towns in search of better

Productivity, climate benefits and the adoption of conservation agriculture in the Highlands of Tanzania

Launched in 2010, the FAO Mitigation of Climate Change in Agriculture (MICCA) Programme is working to make agriculture more climate-smart. One of the programme activities was to test and demonstrate how smallholder farmers can contribute to climate change mitigation while improving their food production, resilience and livelihoods in two climate-smart agriculture (CSA) pilot projects in Kenya and Tanzania.

In the Uluguru Mountains of Tanzania, maize yields and greenhouse gas (GHG) emissions have been assessed from different conservation agriculture (CA) practices. Results demonstrated (see Table) that some CA components significantly improved yields and yield stability, without increasing GHG emissions.

Maize yields under different CA practices compared with conventional tillage

CA Component	Maize yield, t ha^{-1}
Reduced tillage + mulch	2.24
Reduced tillage + mulch + lablab cover crop	2.29
Reduced tillage + mulch + Gliricidia trees	2.83
Reduced tillage + mulch + inorganic fertiliser	2.66
Conventional tillage + broadcast planting	**1.85**

When yields were taken into account, GHG emissions were less than half, with the reduced tillage plus mulch and leguminous trees, and reduced tillage plus mulch and inorganic fertiliser, compared to those from conventional tillage. There is no trade-off between productivity increase and GHG emissions through CA.

The CA components had very different adoption rates, which were dependant on socio-economic and biophysical factors. The adoption of single practices ranged from 31 per cent of farmers for cover crops to 75 per cent for minimum tillage. However, only 20 per cent of farmers adopted all four CA practices in combination (minimum tillage, + mulching + cover crops + leguminous trees). The main adoption determinants reported by farmers surveyed (n = 169) were wealth and food security status, land tenure, land availability, labour availability, perceived payoffs, and access to information and training.

In the MICCA pilots, it was demonstrated that increasing food security, strengthening adaptation and resilience to climate change and mitigating GHG emissions can be achieved simultaneously in the case of CA. However, its adoption faces multiple barriers as innovations in agriculture depend on behavioural change. Assisting farmers with technical support and properly designed extension activities will be key to successful scaling out.

Janie Rioux and Marta Gómez San Juan, FAO

More information on the MICCA pilot projects is available at: http://www.fao.org/climatechange/micca/87067/en/

and more lucrative livelihoods. This means that those left behind (children, the elderly and women) form the workforce, a role that they are less well-equipped to confront. At the same time, there is a general decline in the number of draught animals. In SSA, draught animals are, anyway, restricted to regions free of the tsetse fly (the vector for trypanosomiasis) and other lethal diseases (see also article on pages 14–15). The requirement to provide feed for cattle throughout the year and on-going animal health concerns mean that the use of engine power on farms is becoming more attractive, and currently, there are development efforts being put into spreading the availability of engine-powered mechanisation in smallholder agriculture in SSA. Experience from other regions (Bangladesh is an outstanding example) has shown that the necessary support infrastructure (of fuel, mechanics and replacement parts) grows rapidly in response to the new opportunities. In the case of many SSA countries, the spread of motorcycles and other low-cost engine-powered transport options has often meant that the required infrastructure is already in place. Of course, the use of fossil fuels to produce more food may, in the long run, become unsustainable as the consumption of a GHG-producing, finite and dwindling resource becomes unsustainable.

The most appropriate model for getting more power and mechanisation onto smallholder farms is via the spread of service-providing entrepreneurs. A private sector cadre of providers of climate-smart agricultural production technologies, with their associated backup network of stakeholders will make a sustainable contribution to crop production intensification. But many will benefit from specific training programmes in the concept of SCPI and the correct utilisation of SCPI mechanisation technologies. At the same time, a thorough grounding in the business skills required to run a profitable service provision service to multiple smallholder farmers will create advantages for many others.

For agricultural mechanisation efforts to be successful, it is essential that all players (especially governments) understand the role and place of mechanisation. The public sector has the task of creating the right enabling environment to allow the private sector do its job. The FAO has supported many African, Asian and Latin American countries in the formulation of agricultural mechanisation strategies, the main aim being to bring all stakeholders to the same level of knowledge and commitment for mechanisation. From the public sector, this includes not only the Ministry of Agriculture but also those of Finance (tax and duties), Industries (support to manufacturing sector), Environment (sustainability of mechanisation) and Education (capacity building and formalised training for farmers and mechanics). A mechanisation strategy must, of course, be embedded in an overall strategy of sustainable intensification of agriculture.

Sources for further reading, including detailed information on the projects and examples presented in the text, are available at ➤ **www.rural21.com**

A round tour of mechanisation

What is mechanisation like in different world regions? Which challenges do farmers face in Latin America, sub-Saharan Africa and South Asia? Jelle Van Loon, Frédéric Baudron and Timothy Krupnik, working for the Global Conservation Programme, headed by Bruno Gérard, at the International Maize and Wheat Improvement Center (CIMMYT), give accounts of their experiences.

Jelle Van Loon
is based in CIMMYT/Mexico. He leads the machinery and mechanisation unit focusing on agro-technical analysis of farm machinery and tools. It involves the production of 'easy to follow' machinery construction guides and the design of modular, multifunctional equipment adapted to various farmer's needs.

Frédéric Baudron
is working for CIMMYT in Eastern and Southern Africa, based in Ethiopia. He got into mechanisation R&D from a farming system angle, realising that farm power was a major limiting factor to the productivity of many farms in Africa, as much as good seeds and fertilisers.

Timothy Krupnik
leads CIMMYT's research on appropriate mechanisation in Bangladesh and contributes to mechanisation research and scaling work in India and Nepal.

Rural 21: *Jelle, Frédéric and Timothy, you work in very different regions throughout the world. What is the level of agricultural mechanisation like in these regions, and what impact does it have on day-to-day farm work?*

Jelle Van Loon: Mechanisation levels vary a lot within Mexican borders. In rough terms, the northern states are dominated by big farms with highly advanced machinery and irrigation systems; moving southwards, this gradually changes and turns into subsistence farming with traditional hand tools in the most southern states. In between, there is a mosaic of medium-sized farmers using small four-wheel tractors and smallholder farmers using animal-drawn tools or working with hand planters. Large farmers look for high-precision tools for large fields, while medium and smallholder farmers are stuck between the choice of investing in machines or hiring services. Service providers to medium and smallholder farmers usually lack modern equipment, and so those farmers have limited access to appropriate services. Small tools are in high demand in these farmer groups and include manual equipment, animal drawn-implements and small motorised machinery, including two-wheel tractors. Subsistence farmers rely greatly on non-motorised tools, and here attention should be on functional design and ergonomics, but most importantly on durable solutions.

Frédéric Baudron: In the past decades, both the number of tractors and the number of draught animals have been stagnating – or even declining – in sub-Saharan Africa (SSA). This means that SSA smallholder agriculture is increasingly relying on labour – that is human muscle power. We see labour shortage becoming an issue. This stems from rural-urban migration, an ageing rural population, off-farm income opportunities and the consequences of HIV/AIDS. Today, more than 50 per cent of the cropland in Eastern and Southern Africa is cultivated by hand. Tractors are only used on 20 to 25 per cent of the cropland, and on less than 10 per cent in Western and Central Africa. The history of mechanisation in Africa has been dominated by 'tractorisation' – that is the promotion of tractors with four wheels and two axles – through government-run hiring schemes, since the 1950s or 1960s. Most of these schemes collapsed in the 1990s. 'Appropriate mechanisation' was an interesting alternative movement during the 1970s and 1980s. Small machines are probably more appropriate to the small and fragmented fields of most African farmers and more affordable than large ones. The main problem was that these machines were developed without understanding the demand – no involvement of farmers during the R&D – and with no consideration of their commercialisation – i.e. no involvement of the private sector during the R&D.

Timothy Krupnik: Much of South Asia is already highly mechanised, with over 500,000 two-wheel tractors in Bangladesh alone (although they are used primarily for tillage), 1.6 million irrigation pumps, and over 250,000 threshers. This makes a great platform to build on, as farmers are quite familiar with mechanisation. We focus on more efficient and effective use of machines, especially with respect to agronomic aims like introducing line sowing by seeders that can be attached to two-wheel tractors, or to conservation agriculture practices. In South Asia, we are witnessing a transfor-

mational shift in rural economies where more and more farm family members are migrating to cities or abroad to look for work. In Bangladesh, for example, labourers can typically make more money pulling rickshaws or by gaining employment in the garment industry in the capital than they can by working on farms. Consequently, labour scarcity is increasingly common, despite this country's high population density, resulting in increasing levels of mechanisation. In Bangladesh, much of the machinery that has been adopted by farmers falls into the category of 'appropriate' in terms of being designed for the small-scale, highly fragmented nature of farmers' fields, with mechanisation expanding since the 1990s, owing to policies facilitating the import of inexpensive 8–16 hp engines for two-wheel tractors and associated equipment from China.

In many SSA landscapes, most of the farm power is still provided by men, women, and children. Do you think mechanisation through animal traction is a necessary step to 'engine' mechanisation?

FB: Looking at mechanisation as a 'ladder', moving from manual agriculture to animal traction, then to the use of small machines and ultimately, to the use of a large four-wheel tractor is inappropriate. Patterns of mechanisation have been very diverse in developing countries, and 'big tractors on big fields' is not the solution everywhere. In developing countries, a source of power is rarely completely displaced by another, and as such, manual labour and animal traction is frequently found in countries where motorised machines became common. We should aim at mechanising operations that are critical for productivity gain (for example, timely planting) and operations that are currently characterised by high drudgery (for example, threshing), while recognising that other operations will continue to be manually performed by labourers and draft animals.

TK: I am in general agreement with Frederic's points, although one also needs to note that for engine-based mechanisation to really take off at scale, a diverse set of supplementary markets and services are needed. For example, machines and spare parts first need to be made available on a reliable commercial scale, mechanics must be easily found, and most importantly, a reliable and regular fuel supply is required, although all of this may be underdeveloped in many areas. There are still many parts of Africa – particularly in the Sahel – where one may need to walk two or three hours simply to find a market selling fuel to power machinery. Where this is the case, as an intermediary step, it makes sense to focus on improving farm equipment used in combination with animal traction, as part of a dual-track strategy.

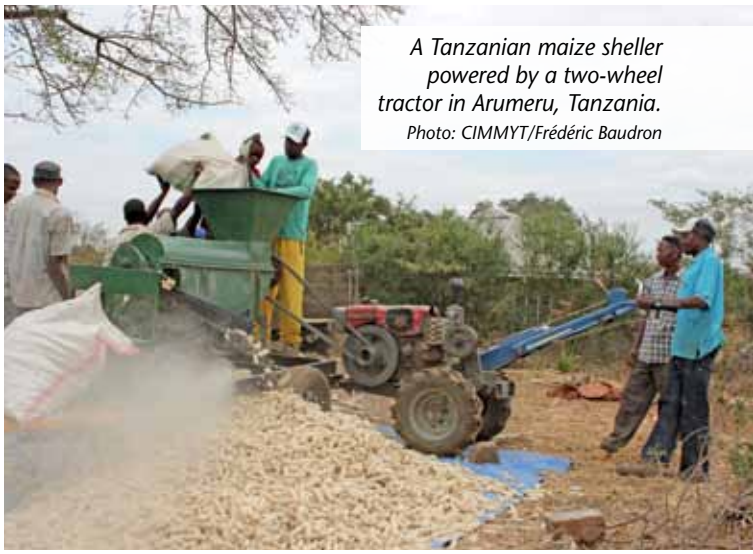
How can we explain the different levels of mechanisation between sub-Saharan Africa, South Asia and Latin America? Any cross-continental learning of interest?

TK: Even within the same region, for example in Latin America, you can have all the 'levels' of mechanisation, depending on the environment, crop, and market systems within each. What is perhaps more useful to think about is farmers' level of access to machinery, and the level at which farm equipment markets have developed. In this sense, mechanisation has certainly taken off more dramatically in South Asia and in Latin America, compared to sub-Saharan Africa. Our research in South Asia shows that mechanisation tends to take off particularly where the underlying socioeconomic and infrastructural conditions are right. We've found that there is more adoption of machines, and consequent service provision to farmers, where rural credit is more available, where electrification is more prevalent, and where road networks are denser, all of which indicate relatively well-functioning markets.

If the level of mechanisation adoption is low in many systems, what do you think the main constraints are to wider adoption?

FB: We need to identify the tasks for which there is a demand for mechanisation, including willingness to pay for a machine or a service. We also need to identify or manufacture suitable machines, and adapt them if necessary. Many two-wheel tractors are sold in Africa with a rotary hoe and a plough, both being pretty useless in rainfed systems. 2WTs can produce enough traction to plough wet paddy fields, but not always the dry soils in rainfed conditions. The demand also needs to be created. Most SSA farmers are simply not aware of the range of mechanisation options that could be available. Importers and manufacturers are present in most countries, but they don't invest in promotion.

TK: We face this problem with some of the improved, resource-conserving equipment that we work with in South Asia, and as a result we have been aggressive in getting the word out about the options available to farmers. Compared to seed or basic changes in agronomic management, which require less investment, purchasing machinery – especially those using engines – is not something risk-averse farmers will take lightly. So, by facilitating arrangements with banks and specific NGOs that can offer lower-risk loans tied to technical support for farmers, and by assuring they are running profitable machinery service provision businesses, some constraints are reduced.



A Tanzanian maize sheller powered by a two-wheel tractor in Arumeru, Tanzania.
Photo: CIMMYT/Frédéric Baudron

You all work for a research programme at CIMMYT that is focusing on Conservation Agriculture. How do mechanisation and CA get along?

FB: This is a completely synergistic relationship: CA makes small mechanisation possible, while small mechanisation alleviates one of the major barriers to the adoption of CA. Why do we need big tractors? A lot of horsepower is mostly needed for ploughing. 2WT tractors are not powerful enough to plough most soils in rainfed condition. But they are perfect to pull simple tines or discs through the topsoil, without inverting it. Therefore, removing tillage, a fundamental principle of CA, makes the use of 2WT possible. On the other hand, the lack of appropriate implements to seed at the right depth through an organic mulch and with minimum soil disturbance is a major constraint faced by smallholders on adopting CA. Delivering mechanised CA to smallholders is therefore a way to stimulate CA adoption. It could also be argued that replacing draught animals by 2WTs would release a substantial amount of biomass – currently fed to draught animals – for mulching.

A service provider in Barisal, Bangladesh, prepares a farmer's field with a bed planter that was the result of research collaboration by CIMMYT, the Bangladesh Agricultural research Institute, and Cornell University.
Photo: CIMMYT/Ranak Martin

TK: Successful implementation of CA requires the right software, in terms of farmers' knowledge on how to move from tillage to no-tillage, use of residues as mulch, and profitable crop rotations. But it also requires the right hardware, in terms of the right equipment adapted to these practices, while being appropriate for the scale of farmers' fields, and for the size of their wallets. Most CA equipment has been developed for large four-wheel tractors in developed nations, where farmers have very, very large fields. While some of the components of these machines will be useful in the areas we work in, machinery needs to be adapted to suit the conditions that smallholders face.

Many large companies overlook smallholders, and focus on implements for wealthier farmers and larger fields. Our work is thus aimed at re-designing and adapting equipment to be more appropriate for lower horsepower tractors, and to the diverse soil conditions and crops encountered in the tropics, while making sure that the machines are produced at a price point that agrees with service providers.

JVL: The principles of CA as a resource conserving practice focus on more efficient use of farm input, including seed, fertiliser, fuel and water. Re-designing and refurbishing machinery – incorporating precise and economical seed-fertiliser meters in small-scale, low fuel consuming equipment that can perform a variety of tasks through a modular setup, which minimises the need for investing in a large machinery package and the complexity of repairs, and this while reducing soil disturbance and soil compaction through controlled traffic, etc. – to work under these conditions goes parallel with the implementation of these agronomic principles. As such, adequate farming techniques can only be promoted if appropriate equipment is available.

You are cooperating with numerous partners. What could still improve in this respect?

FB: We work with importers and manufacturers, mechanisation testing centres and universities, training centres and extension services, NGOs and policy-makers. This cooperation is working out very well. What is missing in most situations is a broker, an intermediary who facilitates linkages between the private sector and smallholder farmers. A broker is not needed where agricultural markets are well-developed and demand is high. In such a situation, the private sector is likely to emerge as the initial and main driver of the chain. Where agricultural markets are weak, demand for machinery and their services is low (because of lack of awareness), and farmers (the clientele) are vulnerable to shocks and stresses, so that a broker is needed to facilitate linkages. Once demand can be assured, intermediaries would be expected to exit, allowing the private sector to step in and scale-out the technologies. In the absence of such a broker, this role is being assumed de facto by projects, which often have neither the resources nor the mandate for this job.

Mechanisation is knowledge-intensive, so what are the knowledge products you are producing, and for whom?

FB: In Africa, promotional materials targeting farmers – our end-users – to create demand is essential. These are mainly posters and leaflets. We also target businesses, crucial 'first users', NGOs, and extension services through factsheets, videos, newsletters and a regularly updated website.

TK: To date, we have developed five 20–30 minute training videos that explain the benefits of the direct sowing, irrigation, and harvesting equipment in South Asia. Videos are then shown in village gatherings to raise awareness, with over 120,000 people having seen the videos since 2013, and

audiences of several million when they are aired on national TV. We are also in the process of developing the first comprehensive compendium of participatory, experiential learning-oriented training modules on appropriate agricultural machinery, for seed drills, axial flow pumps, and harvesters, expected to be completed sometime in 2016. We have also developed materials – open-source technical designs and blueprints – beneficial to manufacturers.

Are there still 'technical challenges' regarding mechanisation?

JVL: One challenge revolves around the practical design of a machine or tool, and this all falls back to the following main aspects: 1) a tool that is versatile enough to work in very diverse soil and farm conditions, 2) a tool that is easy-to-operate to minimise training needs and has an ergonomic design (light weight, user-adjustable configurations) to minimise drudgery, and 3) a tool that is easily repaired and whose parts are readily manufactured or available. A second challenge is the local production capability and manufacturing quality. Equipment with many intricate parts is difficult to reproduce or duplicate. Protocols to ensure a minimum level of manufacturing standard should be implemented.

Finally, challenges definitely arise when thinking about the propagation of functional machinery packages. How can an environment be stimulated into consuming (as in sell, buy, use, and reuse) a different or adapted tool set different from the generally accepted set? The sustained creation of demand for untraditional tools is needed to stimulate the market players, and to achieve this, suitable business models need to be developed.

Last but not least, from some documents you have shared, your mechanisation research for development appears to have a strong gender lens. Can you develop?

FB: Women supply most of the labour in African smallholder agriculture, and are often the ones performing the most labour intensive tasks. Therefore, they are disproportionately affected by the low farm mechanisation in the region. Yet, the solution may not be a simple one of developing women-friendly technologies. It may be more about ensuring that women have access to mechanisation services (particularly in women-headed households) and that women's high labour burden translates into actual demand for mechanisation (particularly in men-headed households). The latter is a more complex issue than the former, as it is about control over resources, intra-household decision-making processes and gender norms.

TK: In many parts of South Asia, increasing migration of men from rural areas to seek employment in urban centres or abroad has resulted in the progressive feminisation of agriculture. In Nepal, for example, many villages are now nearly devoid of farm working age men, leaving many agricultural tasks to women. But most farm machines are not designed

A female welder manufacturing a thresher in Hawassa, Ethiopia.
Photo: CIMMYT/Frédéric Baudron

with women users in mind. Machines may be overly large – even for some of the smaller two-wheel tractors – or lack the ergonomics that would make them easily used by women. We've begun to address these issues by developing equipment that can be used by women to reduce drudgery. Use of mini-tillers and knap-sack seed and fertiliser spreaders are good examples. Where women are less likely to operate machines themselves, as in Bangladesh, where social convention limits women's mobility outside the home or the village, we've worked to back women farmers to facilitate discussions with machinery service providers to get fair prices.

The full version of this article is available together with a wide range of sources for further reading/videos at
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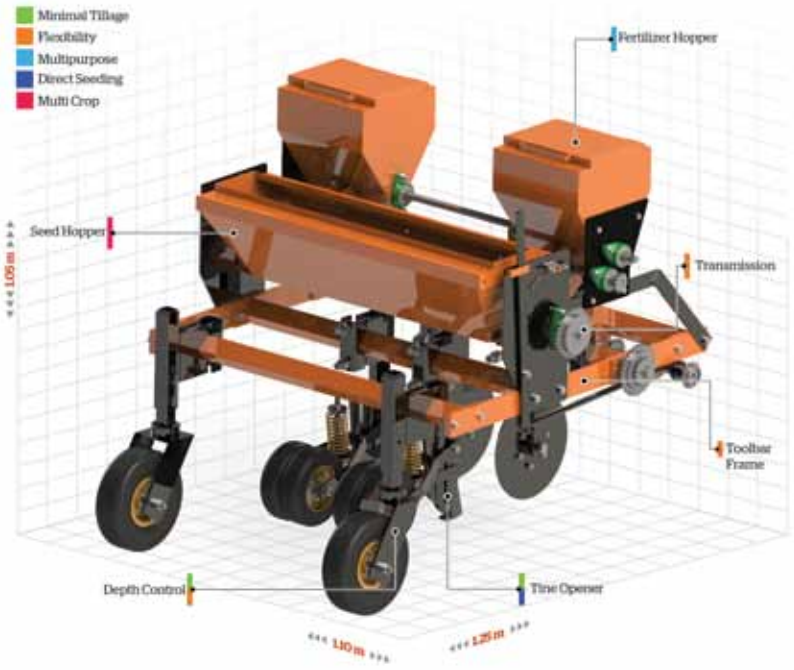
The authors would like to thank all those who have supported their research.



Computer-assisted design: Overview of a multicrop-multipurpose machine and its components to be operated with a 2WT.
Concept: Jelle Van Loon, Gabriel Martinez, Jesus López, Alejandro Klamroth

Animal traction – potential and constraints

Although animal traction would be well-suited to cover parts of farm power demand in sub-Saharan Africa, the use of draft animals has been limited in the region. The authors demonstrate why this is the case in Ghana.

Agricultural development is invariably associated with adequate farm power supply. Many countries in sub-Saharan Africa (SSA) have experienced an increase in food demand in response to population growth, rural-urban migration and urbanisation. As result, there is a growing energy need in the agricultural sector in the sub-region. In 2003, according to the United Nations Food and Agriculture Organization (FAO), only 35 per cent of farm power came from non-human power sources, indicating that there is a big potential for the use of mechanical farm power in the sub-region.

In response, agricultural mechanisation has re-emerged recently in many countries in SSA. Many African governments have made considerable efforts to meet the energy needs of the agricultural sector. In Ghana, for example, these efforts have largely focused on the provision of subsidised tractors to the farming population (see Houssou et al., 2013, p.1 and article on page 20). Animal traction has remained in the background. Meanwhile, the strong demand for mechanisation services and the inadequate number of tractors to meet the demand call for making more effective use of and harnessing other sources of agricultural power to meet the country's growing food needs.

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Animal traction technology is a significant component of agricultural mechanisation. Draft animals are a major source of farm power in the drier rainfed farms of sub-Saharan Africa, especially among small-scale farmers. Some surveys suggest that the technology is still relevant for farming communities in parts of Ghana. Given rising labour shortages in most farming communities, the limited supply of tractor services and regional differences in soil characteristics, working animals are particularly appropriate for farming in parts of Northern Ghana. This note documents the potential of and constraints to animal traction development in the country. The note is a synthesis of research by Houssou et al. (2013) and findings from a survey conducted by the International Food Policy Research Institute in collaboration with Savannah Agricultural Research Institute in 2013 (IFPRI/SARI, 2013). The findings and conclusions in this paper can be extended to other SSA countries where draft animals are used as a source of farm power.

Who uses animal traction, and for what purpose?

Animal traction is an intermediate step to the use of tractors elsewhere, but not so much in SSA. The use of draft animals is widespread in Asia, which hosts the majority of draft animals in the world. Likewise, the adoption of draft animals dates back centuries in North Africa and Ethiopia. In Ghana, animal traction was introduced by the British in the colonial period. As of 2007, only 3 per cent of the power used in the country's agriculture sector comes from draft animals, 2 per cent from tractor and 95 per cent from manual labour. Some parts of Ghana, such as the three northern regions, are naturally suited to the use of draft animals because of the sandy and shallow nature of the soils which requires less traction power than the heavy soils of the humid South.

With regard to farming activities, just like a tractor, draft animals are used to plough, ridge and/or harrow. The technology is also used for carting agricultural produces, water, charcoal and firewood, and for transporting school pupils and farming families. Owners primarily use the animals on their own farms, but they also provide services to neighbours on a hiring basis for cash or in kind. Like tractor users, draft animal users cultivate a variety of crops, such as maize, rice, millet, sorghum, groundnut, cowpea and soybean, among others. They use similar levels of inputs and they obtain comparable yields. Most importantly, the IFPRI/SARI survey also reveals that a substantial number of medium-scale farmers with more than two hectares of cultivated lands rely on draft animals for their power needs.

Is animal traction a profitable technology?

Compared with tractors, draft animals and their implements represent a smaller and more affordable investment. For example, in 2012, a pair of work oxen along with the relevant implements (moldboard plough, ploughshare and yoke) cost about 1,800 Ghana cedis (GH¢), versus GH¢ 17,000 for a used tractor and a plough. Furthermore, ploughing with draft animals is cheaper than ploughing with a tractor (GH¢ 69 versus GH¢ 86 per hectare

The animal traction system can be grouped into five components: the animals, the harness, the implement (plough, harrows, ridges, and carts), the operator and the soil or load, whose changed condition is desired. These components are integral to animal traction, but demand different specialties to deliver a holistic output (changed soil condition for plant growth or position of a load when carting or transporting). For the technology to serve effectively, these must fit each other and function properly.
Photo: Houssou et al.

ploughed). Hence, draft animal users are better off simply using draft power on their small farms when considering the costs associated with the use of the technology for cropland preparation. Nonetheless, the low adoption of animal traction raises the question whether it is a profitable technology at farm level. A previous study by Panin (1989) suggests that animal traction investment is profitable in North-eastern Ghana. Findings from the IFPRI/SARI survey also seem to concur, with 80–87 per cent of draft animal users making profits out of their farming activities. Furthermore, used as a service, animal traction is profitable for owners who combine their own use with services, with 71 per cent (17 of 24) of interviewed providers making profits. These results suggest an economic justification for the use of draft animals in the relevant regions.

What are the challenges faced by users?

The adoption of the technology has been disappointing in most parts of SSA. One of the biggest constraints to the use of animal traction was perhaps the sudden emphasis on tractorisation after post-independence and the wish to bypass animal traction in the sub-region (Pingali et al., 1987). However, pests and diseases, among other factors, have also limited the widespread use of the technology in this part of the world. In Ghana, the more general adoption of animal traction is essentially hampered by design and socio-economic issues. Among the design issues, most of the ploughs and ridgers used in the country are copies of imported European 'Eberhardt' implements, which were developed to suit the larger animals found in temperate regions. Eberhardt design raises the hitching points between the animal harness and the implement too high for the small animals used in Ghana, pushing the centre of resistance far behind the implements. This stresses the animals, imposes undue pressure on the operator and causes early fatigue.

The current withers yokes and the traditional collar harness are uncomfortable for the animals. The yokes' points of contacts are so small that the pressure developed causes harness sores and restricts the animals during work. Furthermore, farmers complained about the fast wearing nature of their ploughshares. Local shares forged by blacksmiths wear very fast because of low hardness values in the metal used. The improved cast steel share, which was developed by local researchers, is not known among animal traction users. Locally forged blacksmith tillage tools are made from scrap metals that are not properly heat-treated and, so, wear very rapidly.

The prevalence of diseases is also a major constraint to animal traction development in Ghana. The breeds of oxen used include the small West African shorthorn, Sanga, and N'dama. These breeds are tolerant of trypanosomiasis, but are not resistant. In areas infested with tsetse flies, the vector for the disease, the work oxen become highly unproductive because of abortions, infertility, slow growth and long calving intervals. But most local farmers and Fulani pastoralists are able to identify the symptoms of trypanosomiasis and, generally, have native knowledge in treating some of the animals' ailments.

With regard to socio-economic issues, there is shortage of labour or young boys who used to operate draft animals due to increasing school enrolment of the youth. Likewise, regions where animal traction predominates are located in the drier part of Ghana. Feed and water availability during the dry season is challenging in these regions. Finally, theft is a key obstacle to animal traction development in the country.

What could be done to support animal traction development?

Just like a tractor, animal traction can contribute to improved agricultural production and food security in many sub-Saharan African countries where the technology is still relevant. Addressing the constraints faced by users of draft animals is likely to create an environment conducive to the development of the technology. Research and policy are essential to upgrading and scaling up the use of animal traction technology. In Ghana, for example, to expand animal traction would require reviving abandoned training centres, assisting local blacksmiths and investing in research on animal traction. Likewise, reduction in labour requirements must be an integral part of improvements to animal traction technology in the country.

For a full list of references, see
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Photo composition A. Trapani, based on photos by J. Boethling (l.), J. Muchoki/giz (r.)

Mechanisation – a catalyst for rural development in sub-Saharan Africa

Modernising and intensifying agricultural production systems is a crucial step towards ending global poverty. Here, mechanisation has a significant role to play, at all levels along the entire value chain. Our authors take the example of potato production in Kenya to demonstrate what options there are and how they can be implemented via a public-private partnership.

Agriculture accounts for about 50 per cent of gross domestic product in Africa. The majority of the population – 80 per cent in fact – works in agriculture. Despite the sector's significance, however, the level of public and private investment is insufficient to unlock its full potential. Strong population growth is putting tremendous additional pressure on the farming sector. Moreover, not only is the urban population growing apace (more people in Zambia now live in the cities than on the land) but the rural population is ageing: young people and the educated are migrating to the cities to seek new opportunities and to earn money. As the urban population grows, consumer spending habits also change. People's appetite for protein in the form of meat and fish is soaring, particularly in many Lower Middle Income Countries (LMICs). Consequently the demand for agricultural commodities is also rising. Agricultural productivity in Africa is largely stagnating, and current supplies are unable to keep pace with the increasing demand. Higher prices could, however, act as an incentive for food producers to step up their output. These incentives would call for investment in infrastructure, education and service provision. Likewise, functioning institutions are indispensable if the rural population is to have access to natural resources (land, water), along with the capital they need to invest, and knowledge provided by agricultural advisory services. Further research into efficient cultivation methods, improved crop varieties and effective farm inputs is required, while more work is needed to improve the diffusion of promising technologies (including mechanisation options).

As a major agricultural production input and a catalyst for rural development, mechanisation endeavours to:

- increase the performance and efficiency of farming activities,
- create jobs (entrepreneurship) and sustainable rural livelihoods,
- promote agricultural development-led industrialisation and markets for rural economic growth,
- improve the quality of primary and processed goods,
- improve working conditions and raise living standards.

Mechanisation has a significant role to play at all levels along the entire value chain in terms of modernising and intensifying agriculture; it creates employment in rural areas – a core element of rural developement – and

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ultimately leads to food security (see Figure at the bottom of the page).

At **production level**, mechanisation is the key operational input for improving the productivity of both labour and land. Machinery efficiently prepares the land for planting without the physical workload, and at the same time ensures that production inputs are used effectively, so that the harvest is of good quality and quantity. Taking advantage of mechanisation at the growing, storage and processing stages also reduces post-harvest losses. A current GIZ study on post-harvest losses of potatoes in Kenya shows that 95 percent of potato damage and loss take place at production level and can be ascribed to inadequate harvesting technology and farmers' lack of knowledge.

At **post-harvest** and **storage** level, a large proportion of production is lost as a result of improper handling and poor storage capacity. Good storage facilities in the form of silos and cooling systems help to reduce food losses and, by allowing farmers to sell their products later, help them fetch higher prices. Such facilities also play a crucial role in the context of food preservation and food security.

In **the processing sector**, the correct technology is a major factor of quality assurance, ensuring that the quality of the end products meets consumer demand at various different levels, and can thus be sold at a profit. In many cases, however, adequate machinery to process agricultural commodities – to grind the grain, press the oilseeds and produce starch from roots and tubers for instance – is simply not available.

Mechanisation and structural change

There is no doubt that if mechanisation is to make a positive contribution to modernising and intensifying agriculture, then it must be introduced correctly. This means it must match local conditions, conserve natural resources and the environment, and increase production. Taking Germany as an example, today only 1.6 percent of the working population is employed in agriculture, forestry and fisheries, but one in nine jobs is associated with agribusiness (upstream and downstream sectors). Over the last few decades, quality and processing of the food have improved dramatically. The huge rise in productivity is a result of labour-saving, highly efficient equipment and the mechanisation of agriculture.

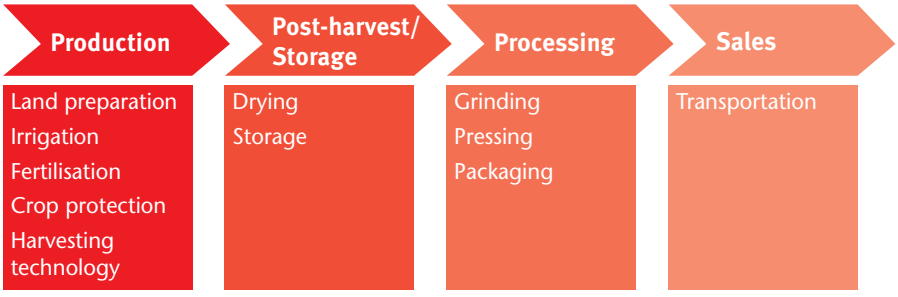
The use of capital-intensive forms of production is thus considered the most important reason behind the fast-paced structural change in farming. To fund this equipment it was vital in Germany that cooperative associations and machinery rings were established. Machinery rings aimed at using the available machinery to capacity and developing additional sources of income have evolved in many regions. They have become a significant economic factor and have also created jobs in the service industry (maintenance and repairs, operation).

Worldwide trends clearly show that there are strong correlations between economic growth and mechanisation; countries which have experienced economic growth during the past 30 years and are tackling their hunger problem have also forged ahead with the mechanisation of agriculture. Countries where economic growth rates have been poor and poverty has remained high, however, have also lagged behind with agricultural mechanisation. If we take the number of agricultural machines in use as an indicator of the progress of mechanisation, then the following can be stated for the past 50 years:

Number of tractors in use (mil.)			
	1961	1970	2000
Sub-Saharan Africa	0,172	0,275	0,221
Asia	0,12	0,6	6
The Near East	0,126	0,26	1,7
Latin America	0,838	0,637	1,8

Compared with the other regions, Asia has seen the greatest rise in tractor numbers (including two-wheel tractors). Changing from the traditional labour-intensive production and post-harvest activities to labour-saving technologies was the continent's answer to increasing workforce shortages, an ageing population and rising labour costs. This development shows the extent to which the region's agriculture has been transformed during recent years. Investment in mechanisation has enabled farmers to intensify production, improve their quality of life and contribute to national and local prosperity. In countries such as India, China, Brazil and Turkey the rapid expansion in farm machinery demand has stimulated the growth of local machinery manufacture and given rise to an important sector of industry. These nations are now major producers of agricultural machinery. While South America and the Middle East have increased their use of farming machinery in recent years, in sub-Saharan Africa tractor numbers actually declined between 1970 and 2000. Even today historical patterns of subsistence farming prevail. The low levels of mechanisation and professionalisation of the sector are worrying. From the point of view of development policy, the solution clearly lies in formulating – and implementing – a national mechanisation strategy which is embedded in national agricultural policy. In the Philippines, for example, the Ministry of Agriculture pursues a mechanisation strategy which aims to in-

Mechanisation potential in the value chain



crease the productivity and incomes of small farmers. Under this scheme, production machinery and post-harvest equipment are purchased from the National Rice Program budget and made available to qualified farmers' groups, cooperatives and communities.

In many cases, however, mechanisation still fails due to a lack of funding opportunities. Individual farmers are not in a position to purchase the expensive machinery on their own. Moreover, in many African countries lack of access to land poses a huge problem, because this means that there is no chance of farmers obtaining credit. Frequently the available technology does not match local conditions and farmers' requirements, and the farmers themselves are poorly organised. There is a great need for financial services to be made available to small farmers, and for cooperatives to be structured to make them an attractive option, thus allowing access to machinery. Training courses and organisational advice should also be made available to those wanting to upskill. The active participation of the private sector is further essential, for instance by providing after sales services (training, repairs, etc.). A lot can be learned from Asia's experience in this respect.

Potato farming in Kenya

In Kenya the potato is an important staple crop which generates an income for more than 800,000 people. The market is growing rapidly as potatoes are becoming an affordable and thus sought-after source of food for the growing urban population. However, production is not able to keep pace with the increased demand. The majority of potatoes are currently produced by small-scale farmers on areas of land between one and five hectares. Most (80%) of the potatoes produced are still being sold through informal markets and consumed fresh.

Most farmers cultivate their land using traditional tools and production methods, which results in low yields (3-7 tons of potatoes per hectare), heavy losses and poor quality. The land is mostly tilled by hand with a hoe. This involves hard physical labour, and only the surface of the soil is tilled. Even where machinery is available, the farmers often do not know how to use it correctly. For example, tractors with disc ploughs are driven too fast over the ground, leaving it poorly prepared for sowing. Planting is also done by hand, which is a time-consuming and laborious task. The lack of storage facilities forces farmers to sell their products immediately after they have been harvested, which makes them unable to respond to market signals. To increase potato productivity and value, machinery should be utilised at the soil tillage and seedbed preparation stage. A tractor with planting machine can be used on small fields from about 0.2 hectares, but its use is only worthwhile if farmers' organisational structures are in place. Crop protection measures should also be carried out using motorised sprayers or – on large fields – tractors. Additional irrigation systems extend the potato season. The use of such machines and creation of storage facilities (cooling systems) could stabilise the potato supply and achieve higher prices. For this purpose, it is essential that farmers organise themselves – in machinery rings/cooperatives or as contractors, for instance, so that they can share the investment costs – and that the mechanisation they opt for is compatible with local conditions and sites.

The Potato Initiative of the German Food Partnership

The Potato Initiative Africa (PIA) is a pilot project within the German Food

Machinery tried out in the Potato Initative Africa

Step in production	Before	Now	Potential benefits
Soil preparation	Hoe	**Rotary Hiller:** For making the ridges	• The machine does two operations in a single run (soil pulverisation and ridging,) hence saving on time and fuel, and also helps to reduce soil compaction. • There is no need to clear the weeds that germinate after land preparation because the rotary hiller does weeding, too. • The operation creates a conducive environment for germination of potato seed. This is because all soil materials that would have hindered or clogged the emergence of young and delicate potato shoots are loosened up. • The machine makes ridges that have the same spacing as the planter hence the whole planting operation is harmonised.
Soil preparation	Hoe	**Bed Former:** For making the ridges firm and solid	• Reduces likelihood of ridges being eroded by heavy rains. • Improves contact between soil particles and the seed. This in return increases soil capillarity for quick uptake of water and minerals by the seeds. • Reduces likelihood of tubers being exposed to sunlight and becoming green.
Planting	Hoe	**Planter:** For potato planting	• Places seeds at between 12.5 cm and 15.0 cm within the ridge which allows quick emergence of shoots during germination. • Recommended plant population is easily achieved since seed placement on the ground is specific and standard as per the settings of the spacing selected. • Heaps soil round the seed which allows good development of tubers. • Earthing up of the crop after germination is not necessary.
Harvesting	Hoe	**Harvester:** For potato harvesting	• Does not damage tubers. • Does not leave tubers in the ground unearthed. • Quite fast in operation compared to using human labour.

Partnership (GFP), which was established in 2012 under the auspices of the German Federal Ministry for Economic cooperation and development (BMZ). Initially the PIA is focusing its efforts on modernising the potato sector in Kenya and Nigeria. Its aim is to develop an integrated concept promoting competitive value chains in the sector, which can then be extended to other regions, too.

To make full use of the countries' potential and foster competitive value chains, new cultivation methods are being tested, opportunities to integrate small-scale farmers in local markets are being identified, and mechanisation options appropriate to local conditions are being introduced. Germany's agricultural sector is involved in the initiative. Companies are making farming equipment and inputs such as seed potatoes, fertilisers, crop protection products and machinery available for testing on (small) farms to establish their potential to increase yields and incomes (see interview below).

The table on page 18 shows the machinery that was tried out during the current growing season. Its impact on yields and incomes is now being evaluated.

"Farmers have to get organised"

Grimme Landmaschinenfabrik is one of the private firms involved in the German Food Partnership (GFP). We asked Frank Nordmann, General Sales Manager Africa, Southeast Asia and Oceania, and GFP spokesperson about some aspects of smallholder mechanisation.

■ **Mr Nordmann, why is your company engaging in the German Food Partnership?**
The GPF offers Grimme the opportunity to combine business interests with a development objective. Within this partnership, we can contribute our expertise for smallholders in Kenya and Nigeria and thus engage in social issues. At the same time, the two countries are becoming interesting as new markets. With Africa's present population of one billion set to double by 2050, we feel that the mechanisation of agriculture is indispensable to maintaining food supplies.

■ **What are your current activities in the Potato Initiative Africa?**
Right now, we are demonstrating machines for smallholder potato growers in Kenya and Nigeria, the aim being to show the advantages of mechanisation in this area. For example, post-harvest losses and damage caused during harvesting can be reduced by more than 30 per cent if potatoes are harvested with a machine instead of a hoe or by hand. Also, the right tillage method and accurate planting can significantly enhance yields.

■ **Which further steps are planned for the project?**
The next move will be to provide machinery via machinery rings, in the course of which the farmers get organised. Each of them invests in a machine, e.g. a potato planter or a bed former. The machines are then shared. The cost of each machine is calculated on a per hectare basis and paid to its owner. We then train the farmers in using and seeing to the maintenance of the machines.

■ **What do you think the greatest challenge is for mechanisation in a country like Kenya?**
We believe that the major challenges in Kenya are, above all, the structure and organisation of smallholders. It's not much use supporting only some of the farmers and leaving out the rest. This is why it is so important for farmers to get organised. Fields need to be accessible, and diseases from neighbouring fields that are not supporting the project must not spread to the fields of the GFP farmers. Here, a single individual can easily wipe out success achieved by many. For us as a medium-sized German business, it is a great challenge to work with the different African cultures and professionally support the projects from where we are. This is why Grimme also has local staff assisting us in the respective countries.

■ **What counts in training the smallholders?**
Training is indeed a key factor, especially the right handling and maintenance of the machinery, and in particular when the project has been concluded. This is the only way to achieve a sustainable impact. Training can either take place in groups on demonstration farms or in so-called outgrower schemes, where a commercial farmer supports smallholder cultivation. The smallholders can purchase seed, fertiliser and pesticides. They can also use the machines without having to invest in them, which gives them access to modern cultivating methods. In addition, there is the option of joint marketing.

■ **Do women also have access to the training measures?**
Women are the backbone of African agriculture. They are integrated and trained throughout the entire value chain, and we also train them in using the machines.

■ **What is the role of the public sector in mechanisation?**
Ultimately, the public sector, i.e. the governments, provides the link between civil society and the local enterprises. Particularly in Africa, it is important to involve local governments and administrations and establish the requirements they perceive and how our projects can be integrated in government measures. A project can only be successful in the long run if everyone is convinced that it is useful and acts in concert. And only then will the project receive the necessary support.

Sustainable mechanisation – a hard row to hoe

Demand for mechanisation is growing again in many African countries. Not only has this been recognised by development cooperation and the private sector. Governments are launching corresponding programmes, too. But have lessons been learnt from the mistakes of the 1960s and 1970s, when state-led mechanisation efforts failed miserably? And what organisational concepts are needed to support sustainable mechanisation which also benefits small farmers? The author describes experiences in Ghana.

Whereas many regions in the developing world have made substantial progress in mechanisation during the last decades, sub-Saharan-Africa is characterised by persistent low levels of mechanisation (1.3 tractors in use per 1,000 ha). This is remarkable because the spread of mechanisation was taken for granted in the 1960s. Both colonial and newly independent countries spent large amounts importing tractors, providing hire services and running state farms. In their efforts, they were assisted by bi- and multilateral aid agreements. However, despite high hopes and big efforts mechanisation rates did not increase sustainably, and these efforts "produced a miserable track record" (Food and Agriculture Organization of the United Nations). Why did these schemes fail so miserably?

Lessons from the past

Ghana may serve as an example. The government imported 10,000 tractors between the 1960s and the 1980s. Most tractors were sooner or later abandoned as qualified operators, technicians and fuel were missing. As a functioning spare part supply was lacking, tractors were also "cannibalised" for spare parts. In general, programmes were successful importing machinery, but failed to prove sustainable after the first stock of spare parts was used and after training programmes ended. Moreover, they were characterised by mismanagement, rent-seeking behaviour and erratic financial support. In addition, scholars argued that there was no actual demand for mechanisation, as e.g. shifting cultivation does not allow for ploughing, nor does it create a need for it. Consequently, mechanisation disappeared from the development agenda.

New drivers of mechanisation

Yet, mechanisation is now back on it as trends such as rural-urban migration, industrialisation and farm system evolution have created strong labour bottlenecks for land preparation in various African countries. Unlike during past mechanisation efforts, smallholders (in Ghana, 60 per cent depend on hired labour) actually do demand mechanisation services. Acknowledging this demand, in 2003, the government of Ghana started importing machinery for individual farmers on a large scale. Also, between 2007 and 2011, the government set up 89 pub-

An imported used tractor. These machines are often old and in bad condition. Frequently, two old tractors are used to create one new one.
Photo: T. Daum

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Few operators have formal training. Most of them learn from the "master" while sitting on the back of the tractor as a "boy".
Photo: T. Daum

lic-private mechanisation service centres (AMSEC) – each of them receiving between three and seven tractors in order to offer services to farmers. The entrepreneurs running the centres paid one third of the actual price of the tractors – and 10 to 20 per cent as a down payment (sometimes a mere 1,000 US dollars [USD] for one tractor). In total, the government imported 3,000 tractors in the last decade. Public spending includes e.g. a 95 million USD agreement with Brazil. Interestingly, in parallel to this heavily subsidised state-led programme, a vibrant market of second-hand machinery evolved under which 3,000 tractors were imported during the last decade. This raises two major questions: Has the state learnt from the past? Moreover, what institutions are needed to support sustainable mechanisation?

Some success, but old problems persist

Although the government praises the AMSEC programme, the evidence is at best mixed. There are AMSECs that work smoothly. One example is the Nso Nyame Ye Women's Group in Ejura (Ashanti), which became one of the first AMSEC, and preferentially serves small and female farmers. On the other hand, the selection process of the AMSECs was not transparent, some AMSECs only exist on paper, and tractors have reportedly been used to benefit party members and friends or have been captured by politicians. Moreover, some AMSEC entrepreneurs who own land themselves use the subsidised tractors received mainly to plough their own fields. In general, the acreage ploughed per year often declined due to frequent breakdowns because of a lack of maintenance, qualified operators and technicians, and spare parts. Some AMSECs concentrate their capacities on the most "promising" tractors received. For example, out of 500 imported John Deere tractors in 2008, six years later, only 200 were still in operation. These problems sound very familiar and resemble the reasons that contributed to the failures of past state-led programmes.

One of the underlying problems of these programmes is the way in which they are funded. Most imports were financed with concessional loan agreements – with emerging countries such as Brazil and India (South-South Cooperation) – which are contested because they are a type of conditional aid. Consequently, the imported brands (mainly Farmtrac, John Deere and Mahindra) changed frequently (as they must often come from the donor country), which hindered the development of a spare-parts supply chain. While farmers purchasing their own used tractors include the accessibility to and affordability of spare parts in their decision-making and mostly demand Massey Ferguson and Ford (30–85 hp), the beneficiaries of government tractors did not have this choice.

Used tractors come from across Europe and are often old and in poor condition – frequently, two old tractors are used to create one new one. The dealers charge approximately 10,000 USD. Yet, while the used tractor market was booming during the last decade, it was heavily hit by the recent depreciation of the Ghanaian Cedi. The Cedi was on parity with the US dollar in 2008, but had devaluated to almost 4 Cedi for 1 USD by August 2014.

The private market

Used tractors are mostly financed with personal savings or credits given by relatives working in cities (sometimes also in illegal gold mining). Banks are reluctant to lend to agriculture because of negative experiences, missing collaterals (80 per cent of the land is held under customary tenure without titles), weather risks, and missing expertise on how to finance agricultural machinery. The application for credit is tedious, repayment is stringent, and the repayment period (12 to 24 months) is not sufficient to finance a tractor. Moreover, the interest rate is high (up to 35 per cent per year). Some banks accept the tractor to be financed as collateral (with a down payment of 30 per cent), but this happens at a rather anecdotal level. Microfinance is only slowly turning to the "rural frontier and to the thorny chal-

lenges of financing small-scale agriculture" (International Fund for Agricultural Development), and has not yet become an option to finance a tractor.

Small farmers marginalised in service provision

The provision of tractor services (i.e. ploughing, maize shelling and transport) is organised around medium and large farmers (10–40 ha) owning tractors and a surprisingly large number of non-farmers (e.g. former extension officers, teachers, shop owners) who see the provision of services as a profitable investment. Ploughing charges vary between 40 and 60 USD per ha. 71 per cent of the tractor owners possess more than 20 ha, and only 4 per cent less than 5 ha (on average 39 ha). Service providers plough between 80 and 350 ha per season and service between 50 and 300 farmers. Yet, they (both private and AMSEC) are often reluctant to serve small farms, because their fields are small, fragmented, spatially dispersed and frequently full of tree stumps and stones. At the same time, there is enough unmet demand from bigger landholdings with better conditions for ploughing. This is alarming as excluding smallholders from mechanisation can lead to an unequal distribution of income and land that is difficult to reverse. Moreover, smallholders waiting for their fields to be ploughed risk a sharp drop in their yields if ploughing (and sowing) is done too late. Besides, smallholders have to accept low qualities of ploughing because their bargaining power is weak and because they do not have other options and are content with being served at all. Women are marginalised because they own rather small plots and low quality land and because tractor owners and operators are mostly male. Some smallholders form groups to address service providers jointly, which reduces transaction costs, improves access to services and increases their bargaining power.

The provision of ploughing services is only profitable if there are no serious breakdowns because the ploughing season is short (45 days in the North), and because it takes several days or weeks to repair a breakdown as access to technicians is limited. Moreover, most technicians are "roadside technicians" who have no formal training. Repairs are often improvised (given the lack of spare parts) and done on a trial-and-error basis. Similarly, few tractor operators have formal training (or a driving licence). Most have learnt from a "master" while sitting on the back of a tractor as a "boy". Consequently, the quality of ploughing is limited. This problem is exacerbated because operators are paid per acre ploughed and, therefore, have incentives to work as fast as possible. They often do not plough in the apt depth, and do not thoroughly cover weeds, and the furrows are not straight. Moreover, operators regularly plough along the slope and adjust their disc ploughs diagonal to cover a larger area, which exacerbates the problem of soil erosion and degradation. This is reminiscent of the "Dust Bowl" in the USA in the 1930s, the socio-economic consequences (including mass migration) of which are illustrated in "The Grapes of Wrath" by nobel laureate John Steinbeck (1939). In many regions, Conservation Agriculture, which entails the principals of soil cover (see articles on pages 6–13), minimal soil disturbance and crop rotation in order to conserve soils, could be the best choice, but it is rarely practised.

Local manufacturers

There are various manufacturers in Ghana who produce agro-processing equipment that can be used on farms (e.g., maize shellers and rice mills). About one third of the tractor owners in Ghana own maize shellers, as providing these services is highly profitable. They are paid on the spot and in kind with one bag of maize for every 10 bags shelled. A maize sheller costs between 700 and 1,600 USD. The quality varies greatly and is often difficult to assess beforehand, as there are no standards or certification. Although local manufacturers have triggered development in other countries, they are not supported by the government and not included in government tenders.

Financial concept: loan guarantee scheme

Banks are reluctant to lend to farmers and have high interest rates. To address this problem, Danish Development Cooperation (DANIDA) set up a loan guarantee scheme (10.9 million USD). DANIDA covers 50 per cent of the default costs of three participating banks, when the banks finance agricultural machinery and when farmers work with outgrowers. This allows the banks to reduce their interest rate (e.g. from more than 30 per cent to 18 per cent). Yet, banks still lose 50 per cent in the case of default and have an incentive to ensure that clients do not default. Some banks cooperate with tractor dealers who cover some part of the interest rate if the tractors to be financed are theirs. Farmers can spread the annual amount of repayment over five self-chosen dates per year and decide themselves which types of machinery (with regard to quality, size, and price and after-sales service) they want to finance.

Rethinking the approach

To sum up, mechanisation efforts in Ghana are driven by the rationale that it is the government's task to make tractors available to farmers. Thereby, major lessons from the past are however not considered. Instead of focusing on the supply of subsidised machinery, the government could be more effective by providing the public goods and services to support the emerging private tractor market. This includes training facilities for technicians and operators. Training could be provided by private organisations with quality assurance by the government, and it could combine the advantages of formal and informal hands on the job training. Moreover, loans to the AMSEC could be made conditional on the servicing of small farmers or on the use of non-till equipment. Experiences from other countries show that creating conducive institutions and policies is more successful than government imports of machinery. In India, for instance, farmers themselves who were ready to invest in machinery drove mechanisation, while the mechanisation policy focused on the provision of public goods and subsidised credit and on creating a conducive business environment.

In Rajasthan, the government programme has supported 16,000 farmers with installing solar warer pumps on their farms, accounting for 40 per cent of the country's installations.
Photo: Dr D. Goyal

Solar pumps and drip irrigation help Indian farmers save water and energy

With dropping groundwater tables and increasing need for energy for irrigation, solar pumps in combination with drip irrigation is the way ahead for farmers in India. More and more farmers are opting for this type of mechanisation – whether with or without government subsidies.

Vena Rangaswamy from Erasi village, Theni district of Tamilnadu, is more popularly known as 'Solar Rangaswamy' in his village. His new identity came from the installation of solar-powered pumps in his farm. About three years back, Rangaswamy was in dire need of additional power supply. He applied for a further electricity connection from the state electricity board – which would cost him 400,000 rupees (Rs) (6,292 US dollars). "Even if I had decided to take that connection, I would have had to wait for it, but I needed power immediately," he says. "I then read about solar pumps in Gujarat through a local agriculture magazine and thought: Why can't we install this here?" The farmer had a drip irrigation system established in his farm 15 years previously because of falling groundwater tables, so a solar pump made sense. Along with drip irrigation, he uses fertigation, a process where fertilisers are sent to the roots of the plants through drip. "The soil is loose with the drip irrigation, and the weed is controlled from the root," Rangaswamy maintains. "I saved almost 96 per cent water with drip irrigation." Many farmers in his village have now installed solar-powered pumps and use drip irrigation to maximise the simultaneous benefit of both these techniques.

The United Nations states that agriculture is the largest user of water, accounting for 70 per cent of freshwater withdrawals. Further, powering the necessary pumps on 300 million irrigated hectares consumes 62 terra watt hours (TWh) a year. Manufacturing and delivery of irrigation equipment consumes another 62 TWh. Hence, 112 million ha or so globally irrigated by groundwater accounts for most of the energy used for irrigation.

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Rajasthan is India's solar water pump leader

The desert state of Rajasthan has just one per cent of India's total surface water resources, yet it holds about 40 per cent of the country's solar pump installations. Its entire population depends on agriculture or horticulture for a living. However, this is often de-

terred by low productivity because of unreliable, inadequate or unavailable irrigation. Around 60,000 farmers are still on a waiting list to get grid-based electricity connections for irrigation, which could take them another two to three years. As 70 per cent of the state is desert, extension of the electric grid is not feasible in distant areas. Moreover, the groundwater level has dropped severely in the last two decades. However, the state has a maximum of 325 sunny days a year, a perfect precondition for solar power.

"Power and water issues have always been there. In a state like Rajasthan, even diesel pumps don't function properly. Then we thought: why not solar?" Dinesh Goyal, former Additional Chief Secretary of the Government of Rajasthan, explains. At the farmer's end, an electricity connection is cheaper than solar pumps or diesel pumps because of the existing subsidies on agricultural power supply. However, in cases where farms are scattered and far off from settlements, the electricity provider has to create the infrastructure to reach the farm, which can cost the farmer hundreds of thousands of rupees.

In 2011, the Rajasthan government started a programme to provide decentralised solar power to farmers (also see box on page 25). Farms seeking to participate had to meet three conditions. First, a water harvesting structure (harvesting/storage structure / groundwater up to 75 m) and a farm size of at least 0.5 ha. Second, drip irrigation was compulsory, and third, horticultural crops had to be grown. "The intention was to bring the farmers out of poverty with cash crops and improve sustainable development," Goyal explains.

The government scheme

The farmers did not have any second thoughts. However, they were worried about having to pay a lot for the solar pumps. "The normal diesel pump cost Rs 60,000–70,000, and the solar pump Rs 500,000", says Goyal. "The farmers said they could pay as much as 14 per cent of the total cost." The Ministry of New and Renewable Energy (MNRE) was giving roughly 30 per cent subsidy for the solar pumps. "We looked at how the remaining 56 per cent could be raised," says Goyal. After a lot of discussions and convincing, Rajasthan Kisan Vikas Yojana (RKVY) – the National Agricultural Development Scheme – offered to sanction the rest.

The installation for the drip irrigation system was subsidised by the National Mission on Micro Irrigation (NMMI). The cost of drip irrigation varies depending on the type of crop, spacing and the area covered. For instance, coconut in 7.5 x 7.5 metre spacing would cost Rs 25,000 per hectare in Tamilnadu. According to this scheme, 50 per cent subsidy is given to farmers, with Central government bearing 40 per cent of the cost and state government bearing 10 per cent. The remaining is borne by the farmer.

The farmers had to prove their interest in the scheme by depositing Rs 10,000. Since 70 per cent of the investment was on the panels, bids were invited from manufacturing companies. The farmers could then select the manufacturer for installing their solar pump. This also gave them the opportunity to talk to the manufacturers about the product in detail. The International Horticulture Innovation and Training Centre (IHITC) in Jaipur provided them with free training on using the systems. This training also offered a platform for farmers to interact and share best agricultural practices with each other. About 100–200 farmers participated in the training. According to an assessment report, "more than 50 per cent of the farmers were able to recover the invested amount in one to two years … All farmers are satisfied with the performance of the solar pump(s)."

Advantages of drip irrigation

Parameters	Flood irrigation	Drip irrigation
Irrigation efficiency (%)	30–50	80–90
Water consumption (cubic metres per hectare)	~ 6,000	~ 3,000
Weed problem	Very high	Reduced significantly
Suitable water	Only normal water	Saline water can be used
Diseases and pest problem	High/moderate	Relatively less
Efficiency in fertiliser use	Heavy losses owing to leaching and evaporation	Very high and constant supply
Yield		20–100 per cent higher

Farmers and the environment are benefiting

The water collected in individual or community farm ponds or storage tanks during the monsoon is used for irrigation, drinking, livestock and other domestic purposes. Water is also stored for a second crop in winter. It is estimated that 17,169 hectares of additional land was brought under irrigation with this scheme in 2012–13. Many farmers even have three crops, and they have diversified to more remunerative horticulture. Additionally, two crops are grown each year, rather than having just one monsoon-fed crop over a whole year. This scheme is still working, but at a slower pace than 2013.

A survey over the 2012–13 season shows that the switch to compulsory drip irrigation has saved 48 million cubic metres of water a year in Rajasthan. Also, 2.4 million litres of diesel, Rs 24 million diesel subsidy and Rs 48 million in foreign exchange has been saved with the combination of solar-drip (also see box on page 25). The beneficiary farmers have saved between Rs 3,000 and 67,000 per annum thanks to using solar pumps instead of electric or diesel pumps. These savings are likely to accrue over the life span of the solar pump, as electricity and diesel prices are expected to rise continuously. Many women farmers participated in the scheme. They attended the training programmes from IHITC and received certificates as well. Under this programme, the drip irri-

gation system has been used in about 34,338 hectares of irrigated land in Rajasthan. Migrating from flood irrigation to drip irrigation has saved about 3,000 cubic metres of water per hectare per annum (also see box on page 24). Hence, the total water saving has been 103 million cubic metres a year for 34,338 hectares of land. This had an influence on energy requirements for pumping out groundwater. Drip irrigation has resulted in improved usage of harvested water for farmers, allowing them to irrigate two or three crops in a year. Moreover, most farmers have not even opened the control box of their motors after installation of the solar pumps; they do not have to go and manually switch the pump on and off, which also saves time.

Subsidy versus non-subsidy

The synergy between harvesting, solar drip and irrigation also applies to Kana Ram Yadav. The farmer used to grow wheat twice a year along with mustard, baby pumpkin and onion in about 1.5 hectare of land. He had two electric pumps of capacities 7.5 hp and 10 hp to draw water from tube wells. His monthly electricity bill was about Rs 1,600 (flat-rate subsidised connection). Now, with this programme, he has a solar water pump of 3,000 W installed on his farm. He also has a water harvesting system of 1,200,000 litres capacity. This sufficiently irrigates his newly created poly-house through drip irrigation and also supplies water to foggers. He uses mulching in a roughly one hectare area of his farm. He now grows exotic cucumber in his poly-house spread across 0.4 hectare and produces about 40–50 tonnes of it a season, twice a year, earning a total income of about Rs 1,200,000 per annum. This is more than five times what he used to earn from wheat earlier. Other technological initiatives have also helped him reduce labour requirement to about 75 per cent.

Both Kana Ram Yadav and Vena Rangaswamy have largely benefited from solar-drip integration to mitigate power and water issues. The only difference is that while horticulture farmers in Rajasthan have been supported by extensive subsidies from the state government, in states such as Tamilnadu, despite subsidies of up to 80 per cent being offered by the state government, many farmers have set up solar-powered pumps through private business houses. They feel that rather than waiting in long queues to obtain subsidies or new connection, they would prefer to get solar panels installed on their own. For Rangaswamy, getting the bank loan was easy as he had a good credit record. Spending a modest Rs 525,000 on a 5 hp pump, his immediate needs were answered, and solar panels were in his farm within a week.

Solar panels can also be used in innovative ways to suit the needs of farmers. For instance, in a farm at Perur, near Coimbatore, in Tamilnadu, a small pond is connected to a solar-powered pump. This pump draws water from the pond that is sent to the farm through drip irrigation to grow coconuts, small onions and sugarcane. When the pond is dry, the motor switches off automatically. Earlier, the farm was mainly irrigated through power supply from the electricity board. When the water was drawn from the pond for irrigation, there was pressure on conventional power from the electricity board. To reduce this pressure, the farm installed a 5 hp solar-powered pump and it helped. Also, the water savings go up to 36,000 litres per hour, according to Jai Shankar, who takes care of the farm.

There is no doubt that the solar-drip combination is looked upon as a boon by farmers. This solution will help them and the government in the long run as we would otherwise face energy and water crises in the future. Steps are taken by the government to ensure that funds are allocated to such projects. Recently, the finance ministry of the Indian government announced setting up of 100,000 solar pumps in the 2014–15 budget. "This is a positive sign and a great beginning to push the use of solar pumps in India," Dinesh Goyal says.

The Rajasthan programme

A pilot project was undertaken in Rajasthan with 14 solar pumps on government farms in 2008–09 and 34 on farmers' fields in 2010–11. The state installed 1,675 pumps in 2011–12 and jumped to 4,000 solar pumps in 2012–13 and more than 9,600 in 2013–14. Until now, they have installed 16,000 pumps (on 16,000 farms) in total.

Measurable indicators (2012–2013; installation of 4,000 pumps)

No. of units (KWh) saved per day	18
No. of electric units saved per pump per year 18 x 200	3,600 KWh
Money saved by solar pumps per year	3,600 x 5 = Rs 18,000
Diesel cost saved per year	Rs 36,000
Diesel saved total, per year (4,000 x 600)	2.4 million litres
Foreign exchange saved per year, crude price at Rs 20/litre	Rs 48 million
Diesel subsidy saved by Government per year (24,00,000 x Rs 10/litre)	Rs 24 million
Diesel subsidy saved by Government in 15 years (Rs 24 million x 15 years)	Rs 360 million
Area irrigated per pump per crop	3 ha
Area irrigated total, 2 crops a year (4,000 pumps x 2 x 3 ha)	24,000 ha
Water required for surface irrigation per ha	5,000 cubic metres
Water saved per ha through drip irrigation (40 % of 5,000)	2,000 cubic metres
Total water saved, 24,000 ha x 2,000 cubic metres	48 million cubic metres
Additional production value due to irrigation through solar pumps	Rs 100,000
Total additional production value due to irrigation through solar pumps	Rs 2,400 million
Total carbon dioxide generation avoided, 12,000 KWh x 0.29 kg	3,480 kg
Curtailment in farmers' waiting list for electric connection	4,000

Sorting out the cocoa maze with pole pruners

A simple pruning machine could help West African smallholders maintain healthy cocoa plantations and enhance yields. However, a pilot project has shown that if innovation is to bear fruit on a sustainable basis, right from the start, education and training is just as important as looking for the right implementation model.

The pole pruner in action in a cocoa plantation. The long extension of the shaft ensures efficient handling and keeps the operator away from the falling biomass.
Photo: J. Soth

Cocoa producing countries all over the world face similar challenges: An over-aging rural population is maintaining over-aging cocoa plantations. Productivity is low and farmers hardly have the chance to develop out of poverty. The factors contributing to this low productivity are little or no investments into inputs, no replanting and neglect of the plantation. Once the plantation has reached a low level of yields, it is very difficult to convince the farmers to engage themselves again in cocoa farming. In light of these challenges actors from an organic cocoa project in Ghana decided to take direct action. The Swiss State Secretariat of Economic Affairs (SECO) encouraged stakeholders to look for creative solutions to combat the particularly challenging aspect of neglected plantations and supported the identified innovation financially.

In neglected plantations, trees have frequently grown taller than 6 metres, whereas around 2.5–3 metres is regarded as reasonable height for a well-maintained plantation that is easy to manage and harvest. In a neglected plantation canopies form a "maze" of cocoa tree branches and epiphytic plants like mistletoes. Since light, air and sun hardly reach the plantation, fungus diseases occur frequently. Unsurprisingly, the yields in such plantations are disappointingly low. 250–400 kg of dried cocoa beans per hectare is reported as typical for the Eastern region in Ghana, whereas the potential of a well-managed plantation can be around 1 ton or even more.

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Pole pruners: easy to handle and environmentally friendly

Hand-tools for pruning do exist, and their use is being taught by several cocoa research and extension organisations throughout West Africa. Nevertheless, the adoption rate of systematic pruning activities by farmers is extremely low, and most of the trees remain unpruned. The work with hand tools is tedious, and at the end of a tough pruning day, progress in the plantation is frustratingly hard to see. The innovation of the mentioned cocoa project was to initiate an experiment with mechanised pruning machines. The German company Stihl, recognised for their quality tools for forestry and gardening, had developed small and robust chain saws (the blade is just 30 cm long) on a 3.5 metre shaft. Originally invented for forestry, these so-called pole pruners turned out to be light and easy to handle in dense cocoa plantations. Unlike hand tools, they allow different sizes of branches to be cut rapidly and large amounts of epiphytic biomass to be removed even when difficult to access. Avoidance of any climbing increases the efficiency of the operations and their safety. But as with many mechanisation innovations, the pole pruners themselves are only one component in a complex socio-economic and institutional setting. The project actors were aware of the essential role of education and training from the very beginning. Therefore many actors (see online version of this article at www.rural21.com) joined forces to organise a training course for 14 participants from farmer-based organisations, Yayra Glover Ltd (the company implementing the mentioned organic cocoa project) and from the governmental cocoa extension service. The course had to master the challenge of balancing the gaining of experience on the machines with profound knowledge of cocoa pruning and machine maintenance. Four days were deemed suitable to teach these practical and theoretical elements in order to prepare the participants for their first real-life mechanical pruning season.

Sixty farms from the Yayra Glover organic cocoa project were selected from a much higher number of farmers willing to participate as pilots to be pruned after the harvesting season 2013/2014. Smallholders are well aware that their plantation management is sub-optimal and appreciate any help coming from familiar and reliable partners.

Since cocoa trees need more than one vegetation period to recover from a radical pruning intervention, only half of the acreage of any of the participating farms was pruned, with the other half to be left unpruned. One reason was that farmers should still have the opportunity to generate income from the unpruned acreage in the season following the pruning. The other reason was the better comparability of the pruning results on the farm itself. Whereas the full results regarding the reduction of fungus disease infestation and productivity gains will only be quantifiable after the harvesting season 2015/2016 (the evaluation report of the SECO funded project will compile these results), the participating farmers as well as many other project farmers are asking for mechanised pruning options. They know their plantations well enough to be aware of the long-term benefits even though the detailed results of the pilot are not yet available.

The pilot has already turned out to be very successful from the point of view of efficiency of the machines in comparison to hand implements. In a period of 20 working days, three trained teams of two people each took turns operating the machines and managed a stunning amount of 23,000 pruned trees, reaching an average of 45 to 65 trees per hour per team. Of cause the state of neglect among plantations varies considerably, limiting the transferability of this average figure. Nevertheless, one can conclude that the pole pruners can reach an approximate tenfold increase in the effectiveness of pruning operations as compared to hand-tools. Furthermore the pilot revealed the success of the thoughtful training. Throughout the entire pilot phase and despite the intensive use of the machines, there has not been any damage to the machines beyond the usual wear of chains and guide bars.

Implementation models

Based on the encouraging results of this pilot, the project partners developed three different models of how the mechanised pruning could be implemented on a wider scale on smallholder cocoa farms in West Africa. Whereas buying a machine for the average one-hectare plantation would mean considerable over-mechanisation and would by no means be affordable to smallholders, the following models were developed with a view to the social and organisational contexts in which such a mechanisation could work:

Farmer group model. A farmer-based organisation buys a machine jointly. Several people in the group are trained in machine handling, maintenance and pruning. However, this model requires an established and well-organised farmer group.

Rural service centre. Small businesses are created that could offer pruning as a payable service to the surrounding smallholder farms. The interesting aspect is that such a micro-enterprise could offer much more than pruning alone. One could think of land preparation and cleaning for new plantations, selling tree seedlings or providing plant protection services. Since the ideal pruning phases are limited time windows during a vegetation period, such a broader range of services might be very suitable. This model requires a good understanding of agronomics on a cocoa farm to find suitable price ranges for the various services that are accepted and embraced by the farmers.

Service by the licensed buying company. The company licensed to buy cocoa in a region could also have trained teams moving from village to village to perform the pruning as a service to "their" farmers. Indeed, the companies are looking for such additional benefits to raise farmers' loyalty towards them. Nevertheless, this model bears the risk that farmers could be selling to other companies and the investment of pruning teams would be lost. This is the model practised right now by Yayra Glover Ltd. Since they have made efforts to establish a trustful relation to the farmers for years, they can offer this service without having to fear that the farmers are selling aside.

Regardless of advantages and challenges of these different models, the pilot also revealed another big opportunity for such a mechanisation approach: the idea of a professional plantation or pruning service creates a new vision for young people to engage in the cocoa sector. In many rural areas the temptation for young people to migrate to the cities is high, even though the outlook for reasonable job opportunities might be grim. A concept of a new profession that is not only economically interesting, but also locally appreciated, will be a very welcome element for the social cohesion in the rural areas of the West African cocoa belt.

The participants of the training course get acquainted with the pole pruners. The training has to combine elements of machine handling and maintenance as well as correct pruning of the cocoa trees.
Photo: J. Soth

Biodegradable mulch – a solution for small-scale horticulture?

Polyethylene sheeting is widely used in vegetable growing to create optimum mulch conditions for seedlings. However, it is a considerable environmental hazard. The World Vegetable Center has tested a biodegradable alternative, which is simultaneously labour- and time-saving, arriving at the result that it is promising but not yet practical.

The widely-used plastic mulches are made from non-renewable petroleum-based material. As a rule, they are used for one growing season only.
Photo: AVRDC

Mulch is a commonly used technology in small-scale vegetable horticulture in Southeast Asia as it helps to control weeds, conserves soil moisture and increases soil temperature which generally has a positive effect on vegetable yield and quality (see Photo above). Also, by reducing direct contact with the soil surface, the proportion of marketable produce (e.g. green leafy vegetables) can be increased, and post-harvest quality may be improved thanks to reduced soil-derived microbial contamination and the reduction of pesticide inputs for controlling weeds. There are different types of mulch, including rice straw and straw matting, but plastic mulch technology has been widely used and promoted by AVRDC – The World Vegetable Center since its establishment in 1973. Plastic of various thicknesses and colours is widely available on the open market and is used by farmers who can afford the additional input cost. In Taiwan it retails at around 0.07 US dollars (USD)/m^2 for material of 35 micrometres thickness which is affordable but yet is a significant contribution to overall costs of production. It can be applied by hand or by machine but in both cases must be strong enough to undergo the application to soil beds without tearing and be able to withstand the initial anchoring process of the plastic to the soil surface.

However, these plastic mulches are made from non-renewable petroleum-based materials, and they are frequently used for one growing season only. Therefore safe and environmentally sound disposal of poly-

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ethylene (PE) mulch is a serious issue in terms of the long-term costs to the environment. At the end of the growing season, the plastic film has to be removed, requiring additional labour, and is then discarded (see top right Photo), and disposed of either by incineration (which can release toxic compounds into the air) or through landfill, where it can be very unsightly, occupying large areas of land, and takes many years to fully degrade. More opportunities for the recycling of this plastic waste would be highly desirable, but this is not often practical or possible in Southeast Asia. In Taiwan, it is possible as the recycled material is used in the plastic injection moulding industry, but substantial quantities of recyclable material must be available at a specific location to make this option economical. At AVRDC's Headquarters, we are using just under three tonnes of such plastic a year, so recycling is feasible.

Looking for alternatives: "Bionolle" put to the test

In order to address this unresolved problem for small-scale farmers, AVRDC is now examining the potential functionality and costs of substituting polyethylene mulch with biodegradable mulch. Such mulches are made from biodegradable polyester or vegetable starches and eventually degrade into water and carbon dioxide, leaving no toxic residues. The time they need until their complete incorporation in the soil varies depending on their composition (they can be extruded with a pre-determined lifetime in the field) and the local environmental conditions and the soil type on which they are applied, and they are clearly a much more environmental-friendly alternative to PE mulch. Such new mulching materials now need suitable testing to assess their agronomic and cost effectiveness.

An example of this type of mulch, "Bionolle", is made from polybutylene succinate (PBS) and polybutylene succinate adipate (PBSA). It has a thickness of 18 micrometres and presently costs about 0.3 USD per m^2.

AVRDC has tested this new material in its technology demonstration garden. The strength of the new biodegradable mulch film proved to be adequate for application in the field by hand or machine but it was evidently not as strong as the conventional PE mulch requiring the initial application process to be handled more carefully. After four weeks in the field in summer 2014 the biodegradable mulch was observed to start to degrade, most evidently on the sides of the bed. After 18 weeks, it had become broken into large pieces and could easily be torn by hand. In contrast, the silver/black PE mulch remained intact and strong. The early break-up of the biodegradable mulch reduced its ability to control weeds and retain soil moisture. Evidently therefore, to use this technology effectively one needs to calculate the likely rate of decay better and then choose a mulch composition quality and thickness to last for the entire growing season of the crop.

The ambient temperature also affects the rate of degradation of the mulch, which progresses faster at higher temperatures because of greater soil microbial action on the mulch. If the mulch degrades too soon, as was the case in this trial, then its agronomic effectiveness is compromised. After harvest, burying the material in soil for a further six months allowed the mulch to degrade into very small fragments which could then easily be incorporated into the soil at the next cultivation (see bottom right Photo).

In this initial test, the material has not yet proven satisfactory for use by farmers in its current state and in tropical conditions, but we conclude that the new mulching material does have a future potential and the concomitant environmental benefits justify further research in this area. AVRDC plans further trials to fine-tune information on biodegradable mulch material thicknesses, quality and their degradation rates over the length of the growing season for specific crops in subsequent seasons.

Large volumes of unsightly plastic waste material awaiting disposal.
Photo: AVRDC

Twelve months after first application on beds (and then being buried in the soil for six months), biodegradable mulch can be easily broken into small pieces.
Photo: AVRDC

A food processing machine that makes a difference

There are many farmers throughout the world who have clever ideas when it comes to optimising their work routines or creating new sources of income. However, they usually lack the institutional support needed to turn these ideas into practice or viable market-ready products. The following entrepreneurial example from India shows how the potential of these grassroots innovators can be tapped for larger social good.

Dharambir Kamboj and his food processing machine (in front). His work has earned him numerous awards, including from the Fifth and Seventh National Biennial Award Function for Grassroots Technological Innovations and Outstanding Traditional Knowledge in 2009 (State award) and 2011 (National first award). He is one of the five innovation scholars selected for First Scholar in the residence programme at the President of India House.
Photo: A. Dey

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Dharambir Kamboj used to be a cycle rickshaw driver in Delhi. While ferrying passengers to a herbal medicine market in old Delhi, he picked up a lot of knowledge about the medicinal plants and their uses. After meeting with an accident leaving him injured and without a rickshaw, he had to return to his village to recover. It was then that he considered putting his knowledge of herbal plants and products to better use to augment his livelihood. He recalled accompanying his mother in his younger days to collect Kesuda *(Butea monosperma)* flowers. These flowers are used to make natural colours for playing Holi – an ancient Hindu religious festival which is also known as the "Festival of Colours". He could not afford education after class ten and started helping his father on the farm.

The first steps

When the idea came up to use his knowledge of herbal plants and products to make a livelihood, Dharambir was using a small piece of land of an acre and a half to grow various medicinal plants and exotic fruits and vegetables like strawberries, button mushroom, baby corn, etc. But he realised that he would not make enough income with primary production alone. After visiting a few fruit and herb processing centres, he started developing a multi-purpose food processing machine. The first prototype was ready by 2006. It was used mainly for extracting juice from aloe vera grown on his farm. Dharambir then modified the machine to incorporate an essential oil extracting facility. One of the salient features of the machine was that it made pulp or juice without breaking the seeds, so the product did not turn bitter or change taste. The device is designed in such a way that it can also be used as a big pressure cooker, a homogeniser or a steriliser.

The Honey Bee Network as an intermediary

In 2007, Dharambir was contacted by Honey Bee Network Volunteers (see box) and staff from the National Innovation Foundation (NIF) India to explore the possibility of helping him improve his machine. Initially, he did not trust the offer, but slowly, after a few interactions, he realised that this was an opportunity to take his indigenous Research & Development to the next

level. "NIF and GIAN helped me to deal with paperwork and gave me money to make a new improved model of the machine," Dharambir said. "I had no reason anymore not to trust them."

His food processing machine had several inadequacies:
1) Cleanliness/ hygiene – its shape and size made cleaning difficult;
2) Safety – the oil jacket was outside, and the motor and wires were exposed, and so was the condenser, causing a danger of getting burnt by accidental touching;
3) Operational – as there was only one opening used both as inlet and outlet, taking out material after processing the fruits/vegetables was a bit inconvenient; and
4) Appearance – with so many protruding parts, the machine did not look elegant.

After receiving technical inputs and financial help (about 1 million rupees [Rs]; 1 Rs = 0.016 USD) from NIF through the Grassroots Innovations Augmentation Network (GIAN) – North, the second model was made. It became smaller and lighter. In 2008, the two organisations helped the innovator with the necessary paperwork – getting a Food Products Order (FPO) license and sale tax number and registering his firm, sending his product for lab testing and filing a patent in his name. In the same year, NIF helped the farmer with a soft loan of Rs 60,000, which he paid back in six months. In the following years, he received additional support totalling Rs 780,000 under NIF's Micro Venture and Innovation Fund (MVIF) scheme, which he also soon afterwards repaid. Furthermore, in 2012, he was granted Rs 180,000 for running a community workshop to support other innovators in his region. Also, the Honey Bee Network facilitated his participation in various exhibitions like the India International Trade Fair (IITF), New Delhi, Agritech India, Bangalore, the Indo-US summit Noida, etc.

However, Dharambir still recognised various limitations of his machine. A collaboration was facilitated between him and a professional designer firm in New Delhi. The new version was a top-feeding design. It had a bigger inlet, was hence easier to clean, and was made of food-grade steel. It was safer, much more elegant and easier to use. Dharambir processes his farm produce in this multi-purpose food processing machine to make various herbal products like creams, shampoos, juices, laddus (sweets) and other processed food products, rose water, aloe vera juice, gel, essential oils, etc. He sells these under the brand "Prince", named after his son. But above all, he sells processing machines. He has sold more than 250 of them so far. He also helps communities and small entrepreneurs to set up their own enterprises. In his processing unit, he employs 30–35 women.

Market development and diffusion

One of the strongest factors in the increasing popularity of the machine is Dharambir's strategy of community capacity building. He travels to different parts of the country, identifies the local resources and trains the communities in making products from them. With his dexterity and the wide adaptability of his machine, he has maintained a strong rapport with his customers and hence has built a strong feedback system. He addresses their complaints individually and effectively. Dharambir also participates in various fairs and trade fairs where he offers free products to everyone visiting his stall. He distributes pamphlets at the fairs and elsewhere. He also markets his product through the cable TV network. He doesn't believe in aggressive marketing and says his customer and others will promote his product through word of mouth.

Innovative from the start

Dharambir remembers the time when he had neither money nor respect and the villagers would mock him and call him insane on account of his proclivity towards making different contraptions. Once, he was bashed up by his father and his brothers, who had also hidden the letters of appreciation which he got for making a low-cost automated sweeping machine in 1995, having been touched by the plight of the sweepers. Earlier, in 1990, he had made a battery-operated spraying machine for his farm, using a tape recorder motor and a small insect trap.

Today, the agro-entrepreneur owns a big house, his children are well educated and settled, and he has a full-fledged manufacturing unit. He sells the machine as well as herbal products. Last year, he was covered by BBC for having paid tax on Rs 7,000,000. He has come a long way and made a difference to the lives of many small farmer entrepreneurs, tribal communities and others. He has participated in several Shodhyatras (learning walks organised by SRISTI, the Society for Research and Initiatives for Sustainable Technologies and Institutions, twice a year) to inspire local communities to leverage their own creativity.

The Honey Bee Network

The Honey Bee Network unites like-minded innovators, farmers, scholars, academicians, policy makers, entrepreneurs, non-governmental organisations (NGOs) and non-governmental individuals (NGIs). Being present in more than 75 countries, the Network's philosophy is that in order to become sustainable, a knowledge system has to be both just and fair. Hence, while collecting knowledge, the Network has made it a norm to acknowledge, attribute and reciprocate the knowledge provider with name and reference (unless desired otherwise by him or her). The cross-pollination of ideas helps enrich communities through people-to-people learning. Out of any financial gain that accrues from the value addition in local traditional knowledge and innovation, a fair and reasonable share goes back to the knowledge holders. A further premise is that people's ideas are shared in an easily understandable manner in the local language. In India, every summer and winter, volunteers pursue learning walks (Shodhyatras) to share and learn from creative communities, generally in the most neglected areas of the country. More than 5,000 km have been covered through these walks so far.

More information: -> www.sristi.org; www.nifindia.org; www.gian.org

Adaptation to climate change – there is much more to it

Adaptation to climate change in agriculture is a hot topic, but what exactly does it mean? Our authors suggest to take a step back before embarking on adaptation work in rural development, and to carefully clarify the goals of adaptation and scrutinise the role of rural development organisations in adaptation processes.



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Adaptation to climate change is of paramount importance for agriculture and for rural communities. It is high on the agenda in rural development, both on a conceptual level and in daily project work. However, is it clear what adaptation to climate change in agriculture means? Is it clear how to measure the success of adaptation strategies? We argue that formulating the goals and designing measurements for adaptation success in agriculture is much more challenging than commonly thought. In fact, adaptation to climate change brings neglected dimensions of rural development work to the fore, calling for a thorough reassessment of how to best engage in this work.

The challenge

Predictions of climate change impacts on agriculture entail increases in weather extremes such as droughts and floods, shifts in cropping seasons and increased pest and disease pressure. Adaptation to climate change aims at decreasing the vulnerability of rural communities to these changes, thus seeking to maintain or improve their agricultural production capacities despite increasingly unfavourable conditions. Increased water and nutrient use efficiency of crops, drought resistance and improved pest and disease management are important building blocks of adaptation strategies, and there are many successful examples of projects that support improved agricultural practices for adaptation.

However, one key challenge of adaptation work is the time horizon of several decades rather than just a few years. Furthermore, adaptation has to deal not only with gradual changes, but with fundamental system transformations at certain threshold levels. For example, increased water use efficiency helps to deal with increasing water scarcity, but beyond some level of scarcity, agriculture may have to be abandoned. The goal of adaptation is thus twofold, and very diverse. First, it aims at keeping the vulnerability of production systems to the impacts of climate change low, maintaining the production capacities. If this can no longer be achieved, its second aim is to provide communities with the means and capabilities to change their livelihood sources to less vulnerable ones. Adaptation strategies can then become very fundamental, such as switching from crop production to grassland-based animal husbandry or even abandoning agriculture altogether as a source of livelihoods, taking up other activities or migrating to other regions.

The conceptual literature is well aware of the need to address the time horizon of decades and the possibility of fundamental transformation in adaptation. But these topics hardly play a role in current adaptation projects, which focus on improving production practices, crop choice and varieties, access to inputs, output markets, credits, information and extension services for farms or farming communities, and they usually operate within time frames of just a few years. As important as this is, it falls short of the necessary far-reaching perspective on adaptation.

Adaptation from within

Unlike the neglected decade-long time horizon and transformation processes, participatory approaches are often supported in adaptation work. Stakeholders should "own" the process and its goals. Strategies, implementation, and monitoring should be developed from within the community in a participatory manner. This is even more important for time-frames of decades and fundamental changes in the livelihood basis of communities. Such changes concern aspects

of regional or national sovereignty and responsibility. For example, visions are required on the structure of the agricultural sector in 20 years, alternative income sources need to be identified, or even relocation might have to be considered. Not only are farmers' livelihoods at stake but a community's future as a whole. Moreover, communities' futures have to be assessed within the socio-economic context of the regional and national economy and potential governmental development strategies and institutions. Ultimately, this means that regions and nations need to "own" adaptation processes, besides the people and communities directly affected.

Adaptation thus involves governmental core responsibilities. While we criticise that current project-based rural development work often disregards the full extent of adaptation, accounting for it is not free of problems either. If non-governmental actors take over governmental tasks, the danger that this will happen in an uncoordinated and inefficient way is all too real. Disaster relief in Haiti after the 2010 earthquake may serve as an example. Hereby, we clearly do not assert that governmental action is always coordinated and efficient, alas! But we want to point out the challenges and responsibilities that arise when embarking on such tasks. The success of single improved adaptation practices, e.g. higher water use efficiency by organic soil amendments, can be measured within few years. Measuring long-term adaptation success of a community, however, is only possible after decades. In the timeframe of a few years, it could at best be identified whether a community has the capability to start towards a future adaptation goal, e.g. via an assessment of its current resilience capacity and its capacity for transformability in face of drastic changes in livelihood basis. Many suggestions for such assessments exist. Participatory approaches, institutions that allow for learning and innovation, diversity in activities, livelihood basis, input sources and output use are generally seen as prerequisites for successful adaptation. Furthermore, defining criteria for successful adaptation is difficult. Is adaptation success that in 20 years, stakeholders are still performing the same activities that they are now? Or is it rather that key indicators such as poverty levels and food security have not deteriorated? Or is it that all stakeholders are able to live a decent life, however defined, and wherever lived, thus also conceding that migration can be a successful adaptation strategy? Indicators for adaptation success need to relate to the developmental goals of a rural community, and defining or identifying them is a challenging task.

The role of rural development work

Adaptation projects thus operate in a context of high uncertainty, in particular on future developments and often also on future goals. It is important to support measures that are robust in the sense that they lead to beneficial outcomes in a broad range of situations and that they strengthen processes and institutions that increase the capability to successfully deal with unexpected thresholds. Much is known on broadly beneficial measures at the level of agricultural practices, such as soil protection, increased crop diversity and improved water management. Many promising rural development projects on climate change adaptation in agriculture apply such measures. However, these activities need to be complemented with activities to address the challenges of a time horizon of several decades, the possibility to undergo fundamental changes, and the fact that related actions are core tasks of governments.

While daily business must continue and is demanding, we strongly suggest that rural development workers and organisations take some time to develop long-term visions on their approach regarding climate change adaptation in agriculture, in close exchange with the target communities and their institutional context. Such projects are not only about improving the agricultural livelihoods of people. There need to be visions on what the target communities and regions may look like in 20 or 50 years, given some assumptions on future climate change. Such visions may even foresee drastic reductions of farm household numbers and population shares depending on agriculture. Adaptation work aims at making people fit to live in an adverse environment or making such an environment less adverse, e.g. by improving irrigation infrastructure or by assuring minimum prices for certified products. However, it should also prepare people and communities to deal with future fundamental and maybe unexpected changes.

Ideally, people and communities start preparing for changes while there is not yet an urgent need for change. This is easier if actions taken are comprehensible now and not only in a distant and hypothetical future situation of change. Visionary first movers with a strong internal motivation to deal with these issues should be part of these current activities. On the other hand, the momentum that emerges when the need for change becomes imminent can then complement such preparatory efforts and can be used to foster fast change. Crisis can be a big driver for change. The key is that communities are well prepared for this and dispose of the means and capabilities to successfully deal with crisis.

Again, we emphasise that the aspect of fundamental system changes within adaptation work is particularly sensitive, as it touches on core responsibilities of governments. It becomes all the more important that paternalistic approaches in rural development work are avoided and that activities for adaptation work are well-coordinated and participatory. Governmental institutions may not take up all challenges related to adaptation, though. How to deal with this in adaptation projects has to be thought through cautiously and in detail. Current adaptation work in rural communities achieves much, but it lacks awareness for decade-long time horizons and fundamental changes. People working in adaptation projects need to take this seriously. Visions for the distant future accounting for the possibility of fundamental changes need to complement and guide current adaptation work.

For references and further reading, see ➤ **www.rural21.com**

The authors would like to thank the Mercator Foundation Switzerland for funding.

Groundnut is the only cash crop in The Gambia. During the dry season, women are busy peeling the nuts under the shade of a mango tree.
Photo: S. Eibisch

Cereal banks in The Gambia – a case study

During the 1970s, when severe droughts affected West African farmers, cereal banks became popular in the region. However, things quickly became very quiet again about this type of food security scheme, probably also because many of the cereal banks failed. Scientific surveys addressing the topic are scarce. A study in The Gambia in 2014 investigated how such cereal banks function and what the important variables for their success are.

Agriculture is the key sector and most important source of rural livelihoods in The Gambia. Generally, the length of the rainy season is becoming more variable. A distinct period in the agricultural calendar is the so-called ´hunger season´ when rain falls sporadically in the period from August to September. At this point domestic grain stores usually have run empty, hence food prices in the market multiply while farmers must begin the exhausting labour of preparing their fields for the upcoming season. Thus, the crops from the old harvest are eaten and the new crops are still about to grow. Farmers need to open up alternative income sources in order to be able to buy costly cereals at the market. Turning to non-farm work or eating cereals that were stored to serve as future seeds would endanger the next harvest.

In 2014, a qualitative geographic study was conducted for the West African Science Service Center for Climate Change and Adapted Land Use (WASCAL). It was to establish how cereal banks work in the Gambia and which variables indicate success or failure. For this purpose, seven villages were examined on both sides of the Gambia River in the dry season of 2014.

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An idea gains ground

Burkina Faso is thought of as the country where the idea of cereal banks originated from. During the 1970s, when severe droughts were affecting West African farmers, cereal banks became popular in the region. When exactly they gained ground in The Gambia could not be determined in the study. One helpful reference point was definitely the co-evolution of stone-made seed stores which were constructed by the government and

non-governmental organisations in order to reduce the loss of crops during storage by insects or fire in the 1980s and 1990s.

A cereal bank is a community institution that awards cereal loans to the village inhabitants during the rainy season that are repayable with a small extra charge after the harvest. Typical crops that form the loan in cereal banks in The Gambia include millet, sorghum, rice and maize, which are stored there until needed to support the family kitchen. In this way, farmers are prevented from selling cereals at low prices when there is an excess supply shortly after the harvest. This means that they keep most of their food and do not need to buy it later at a much higher price, when cereals are rare and expensive because of the hunger season and the upcoming sowing season. Cereal banks in The Gambia are built with funds from either the government or donors (World Bank, Social Development Fund, ActionAid), although some communities have initiated them on their own.

How do the cereal banks work?

According to scholarly definitions, a cereal bank is a rural organisation to secure food security by buying, storing and selling grain which is managed by a committee. This committee is usually appointed by the user community. Cereal banks in The Gambia operate completely without money. The entire loan process is organised 'in kind'. This characteristic makes cereal banks suitable for community management and self-sustenance. The only support that might be needed is the construction of the storage house. But suitable buildings already existed in many villages as a result of the construction programmes in the 1980s and 1990s. The buildings now belong to the community, which can choose how to make use of them. Thus, in theory, external support consists solely of an initial stock of grain which is supplied and added to the deposit by a non-governmental organisation, but in some cases advisory support and further training on management issues is recommended. Once the cereal bank is well-stocked, the Village Development Committee (VDC) and the village community may agree on the conditions for the repayment of loans. These may include interest rates or penalties. The loans are paid out again during the rainy and the "hunger season". Loan-takers usually have to repay their loans and interest rate in-kind after the next harvest. The interest helps to increase the stock of the bank. It can also be sold to cover maintenance costs of the storage house.

Village Developement Commitees were established in The Gambia as part of the Local Government Act of 2002. They are elected by the rural communities. Usually, the VDC leads the cereal banks after appointment by the community. VDC members are volunteers who engage in many different development and village issues. Therefore, it seemed self-evident to make them oversee the cereal banks as well.

There is no formal membership of cereal banks in The Gambia. The banks operate as a village project, and every family that needs food may ask for a loan (unless the stock is exhausted). All of the interview partners in the study said that the entire village was running the cereal bank and all families benefited.

Seed storage houses are found in most of the villages in The Gambia.
Photo: S. Eibisch

Cereal banks secure farmers against post-harvest losses and buffer local volatility in food prices.
Photo: S. Eibisch

Variables for failure and success

For the survey, seven villages which are spread in the hinterland of The Gambia were examined, giving more information on cereal banking set in different ethnic backgrounds and population densities. Results from the case study showed that many of the initiatives observed had started falling apart when NGOs and other donor organisations withdrew from supporting the cereal banks and the VDC members were left alone with the management. Three of seven villages had lost their cereal banks by the time of research. And even the failed cereal banks had worked for three to nine years before their breakdown. Their users had low incomes and had had difficulties paying back their loans. Other poor farmers looked at those users who did not repay and felt that these had gained an additional economic profit. Others then also refused to pay the loans back – starting a chain reaction which undermined the operation of the cereal bank. This had happened in at least two of the villages observed. Once, the complete breakdown of the cereal bank took less than a month.

Why did some cereal banks fail while others succeeded? How could the willingness to repay loans be ensured and by whom? The case study

identified four crucial variables: leadership, collateral security, peer pressure and sanction capability.

Leadership matters. The traditional and political leader in Gambian rural communities is the Alkali or Alkalo. One of the villages with strong leadership and a well-working cereal bank is Changai Wollof. Changai's cereal bank provides about 2–3 bags of cereals (50 kg each) for each household head of the 800 inhabitants each year. When asked about the repayments of loans, one committee member answered: "If you don't pay we will take you to the Alkali. And if the person still insists on not paying then we have to take the person to the district chief but, in fact there has not been any instance that we have taken someone to the Alkali. The Alkali helps us collect our loan." Farmers often seem to comply with the rules of the cereal bank, indicating the authority and standing of the Alkali amongst his villagers, because they fear the disgrace in front of the Alkali when he is a strong leader and sets a good example.

The above-described impact can be reversed if the leader does not follow the commonly agreed rules on loan distribution. This has been observed in two of three villages where cereal banks had collapsed. Since the authority of the Alkali cannot be publicly questioned, his refusal to repay loans weighed much heavier than the default of a simple farmer. A local consultant gave a similar description of this phenomenon: "If the village head himself happens to default, some other people will say, look, when the village head has defaulted and he is not paying, so why I am going to bother myself with paying."

The practice of collateral security. Six out of seven villages in the study demanded collateral security from their users if they wished to take up a loan. This 'guarantee' was usually an agricultural tool for sowing (a seeder) with a value of approximately two bags of cereals. In case of a refusal to pay back the cereal loan, the guarantee could be sold. This practice differed amongst the villages. In the village of Medina Sancha, with mainly a Wolof population, the cereal bank was operating without problems. The secretary of the committee explained why: "It's because of the guarantees. If you give loan to anybody without a guarantee, he will not repay it – not only in this village."

Peer pressure and gender. The community in Changai Wollof are operating their cereal bank without problems, too. And they do not ask for collateral security. Here, the authority of the Alkali seems to motivate users sufficiently. The Alkali of Changai Wollof takes advantage of the fact that not paying back the cereal loan is a public disgrace that is feared by all villagers. The study revealed that women in particular responded strongly to such peer pressure. This is also the case in Medina Sancha, where women are exempted from providing the collateral security. A committee member explained: "Everybody gives guarantee except for the women […] Because when it comes to the loan issue, women are more reliable than men. Because whatever you give a woman, she would stake her life to pay it back, because she would not want to go out and have her fellow women telling her that she has not paid."

Public disgrace is just one side of the coin. If the community feel exploited by individuals, they may also turn against the culprits and deny them all mutual support that rural households in The Gambia depend on. "… they will isolate you, and you won't get money, nor help for problems, nothing," claimed a youth leader in Changai Wollof.

Sanction capability. In some cases, a collateral alone cannot ensure repayment. All three villages observed with collapsed cereal banks hesitated to sell the collaterals they had collected before. This motioned the wrong sign to the other users. A chain reaction was set in motion. The Committee needs to be very strict, even if the debtor is poor or just unfortunate. If the committee perceives the strict punishment not suitable, it needs to find other opportunities to help the person without abating the cereal loan. This shows that guarantees alone do not sustain a cereal bank. It needs the willingness to actually sell the collateral in order to fill the cereal deposit again.

Conclusion

There is consensus about the important role that cereal banks can play in providing food security. The largest share of the villages in the study had been operating their bank without external support for the past few years. The functioning cereal banks operated economically and were able to cover expenses for maintenance. Thus, success stories of cereal banks can be found in The Gambia and provide a learning ground for users, researchers and development workers alike.

Cereal banks in West Africa

In the early 1990s about 3,300 cereal banks were counted in West African countries including Burkina Faso, Senegal, Niger, Mali, Chad, Mauritania and The Gambia. In the following years, they came a bit out of fashion, only to enjoy more support again from government and non-governmental organisations at the beginning of the new millennium. By 2008, for example, 4,000 cereal banks were operating again in Niger. Reliable statistical data is not available for the other countries since there are hardly any scientific surveys on the topic.

The study "Cereal Banking in The Gambia: In search for adaptation to climatic variations on the community level" was conducted for the West African Science Service Center for Climate Change and Adapted Land Use (WASCAL) and supervised by the University of Bonn (Department of Geography and Center for Development Research), Germany. WASCAL was initiated by the German Federal Ministry of Education and Research in 2010 and is acknowledged as an international institute by the Economic Community of West African States – ECOWAS (see also: www.wascal.org).

Women selling their produce at a market in the Morogoro Mountains. Like in many other African countries, women constitute the majority of the agricultural labour force in Tanzania.
Photo: P. Monteil

Making markets work for the poor

Lack of access to markets is a problem for numerous small-scale enterprises in Africa. In order to overcome the existing bottlenecks and to facilitate smallholders' market participation, the Swiss Agency for Development and Cooperation has been working with the Market Systems Development (MSD) approach for several years – and successfully at that, as the following example from Tanzania shows.

In many African economies, the rural situation is marked by continuing stagnation, poor production, low incomes and the rising vulnerability of poor people. Poor families are often excluded from all kind of formal markets, i.e., they cannot participate systematically in interactions between different market actors. They may put up some products for sale from time to time, but because they have only very small quantities to sell and lack information about recent developments such as prices or opportunities, they are in a weak position without bargaining power. Encouraging smallholders to increase their production is not effective if they do not have the possibility to sell the surplus products on a market and if they do not have access to the commodities necessary for production. This insight is not new, but for a long time it was not given enough attention. Interventions by donor-driven projects have often even aggravated the trend rather than reversed it.

In a market system (see Figure on page 38), a number of formal and informal operators are involved, who need to interact according to various rules with one another to make the market operate. The approach called Market Systems Development (MSD) tries to identify the constraints within a value chain and to recognise the reasons why a market is not functioning properly. Project interventions address these limitations by developing ways to overcome the bottlenecks and by facilitating different market players. The idea behind the approach is that involving smallholders will bring income and employment benefits to them. Therefore the question is not "what problems does the target population have and how can we solve them?", but "how can we address the constraints that prevent the poor from participating in a market?". The focus is then on developing market systems, considering the different roles and functions public and private, formal and informal, stakeholders have and finding ways that smallholders can participate in the market. Therefore MSD is an indirect intervention into market systems, which means that a project facilitates market activities by catalysing market actors and inducing

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systemic changes, while staying external to the system.

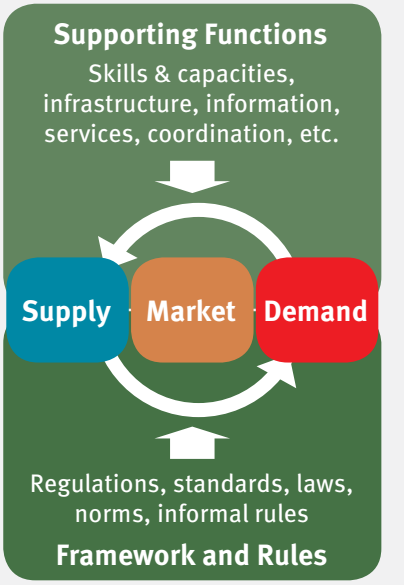
Facilitating activities may differ over a broad range: technical assistance to supply-side players; coordination between small producers to improve their bargaining and purchasing power in markets; offering information to market players; introducing new business ideas and providing technical support to develop them; limited financial support to defray initial risks; providing technical assistance and some financial support to regulators and researchers to improve the process of policy analysis; and developing new commercial services and other measures. Markets that are "working for the poor" offer job opportunities, adequate returns on commodities and products, and enhanced affordability of products and services for the poor.

The Swiss Agency for Development and Cooperation (SDC) has a long track record on working with the MSD approach. One project of SDC's programmes in East and Southern Africa applying the MSD approach is exposed here as an example.

The Rural Livelihood Development Programme in Tanzania

Tanzania's economy is highly dependent on agriculture, which accounts for about 45 per cent of GDP and two thirds of the export earnings. The agricultural sector is the main source of employment and livelihood for three quarters of the population. Women constitute the major part of the agricultural labour force. Tanzania's agricultural sector is dominated by smallholder farmers, carrying out rainfed agriculture and producing a variety of subsistence crops, such as maize, sorghum, millet, cassava, sweet potatoes, pulses, paddy rice, wheat and fruit and vegetables. On average, rural households own five acres each. There are many major constraints in the agriculture sector as e.g. poor and disease-prone seed, declining land productivity due to outdated farming methods and impoverished soils, a decreasing labour force due to urban migration, and unreliable weather conditions. Nevertheless, 85 per cent of Tanzania's poor people live in rural areas and rely on agriculture as their main source of income and livelihood. The agricultural sector fails to make significant inroads into high levels of rural poverty and household food insecurity. Reality is characterised by very low wages, regular food shortages, and barely functioning markets. Despite the fact that women represent the major part of agricultural labour force, they do not have equal access to productive assets, inputs and services, and therefore they produce less.

The core of a market system represents the central set of exchanges between providers (supply side) and consumers (demand side) of goods and services, which is at the heart of any market.



In this context, SDC started the Rural Livelihood Development Programme (RLDP) in 2008. The programme, implemented by a consortium consisting of Helvetas Swiss Intercooperation and Swisscontact, aims at making market systems work better for the welfare of rural producers in the Central Corridor of Tanzania. Its overall goal is to improve the livelihood of target households by opening up their access to local, regional and national markets. Being able to sell and buy products on a market is important for improving the fragile balance between food production and income, so access to a market will finally contribute to finding a way out of extreme poverty. The project supports four key value chains, namely cotton, sunflower, rice, and poultry. It also facilitates a radio programme and rural advisory services (see Figure on page 39).

All interventions add to the creation of win-win situations: producers improve their access to information, knowledge, inputs and market services, which contributes to generating additional income. On the other hand, processors, through investments in the respective subsector, can enhance their business. Mutual mistrust has to be reduced; participants are increasingly willing to accept the interdependence. Private companies realise that they have to invest in their business instead of simply purchasing products from farmers. These investments cover infrastructure and hardware such as transport systems, ginneries, warehouses, etc., and superstructure or software such as agricultural extension, inputs distribution systems, seeds, etc.

RLDP facilitates the establishment of long-term collaboration between value chain partners (producers, processors, traders, retailers) and local government authorities e.g. for the provision of extension services to producers. Depending on the sector, the income of households has risen between 28 per cent and 96 per cent (production of quality sunflower seed from 790,000 Tanzanian Shillings (TZSh) to 1,010,000 TZSh; sunflower from 100,000 TZSh to 170,000 TZSh; cotton from 270,000 TZSh to 530,000 TZSh); in the commodity sectors, the cumulative outreach of RLDP is more than 75,000 households. The following two value chains serve as examples.

The sunflower value chain

Sunflower is a major cash crop in Tanzania and involves around 250,000 households with an area of

one to five acres, mainly cultivated by hand. More than 60 per cent of sunflower in Tanzania is produced in the Central Corridor. The sector contributes 40 per cent of edible oil. Business opportunities exist along the entire value chain; the cultivation of sunflowers requires only low investments by farmers. The market demand for sunflower oil and cake is steadily increasing: demand stands at 330,000 tons per year, while the actual production is only 200,000 tons.

RLDP has started facilitating a broad range of market activities, e.g. producers benefit from various services ranging from improved access to inputs such as seeds, fertilisers, pesticides, tractor services, and canvases for post-harvest management, and they benefit from advisory services as well. RLDP furthermore introduced a contract farming model as a way of improving productivity and sales of sunflower at farmers' level (see Box on top). Other interventions are aimed at building a better relationship and harmonisation between small farmers and sunflower oil processors. This and the higher yields per unit area along with the better prices have led to an expansion of cultivated area – an important point for processors because it has also improved the profitability of their investments. It further stimulates sunflower oil seeds cultivation in other areas outside the Central Corridor, and production in the country has increased annually from 305,000 tons to 786,000 tons. More than two thirds of the nearly 30,000 households reached have established contracts with buyers; of these, almost 30 per cent are female producers. Thanks to improved agricultural practices, ameliorated sunflower seeds are now available to farmers, and the quality of the grains reaching processors has improved. The use of quality seeds coupled with the improvement of other agronomic practices has increased the yields from 200 kg up to 350 kg per acre.

Until recently, because of the low repayment rate, the banking sector was reluctant to extend credits to processors. Thanks to an intervention of RLDP, one bank accepted sunflower already bought as collateral for loans. As a result, processors acquired new and competitive technologies for processing oils. Finally, over 40 processors were able to invest 3.5 million US dollars to increase their processing capacities. This, in turn, has increased the sales potential of smallholder producers.

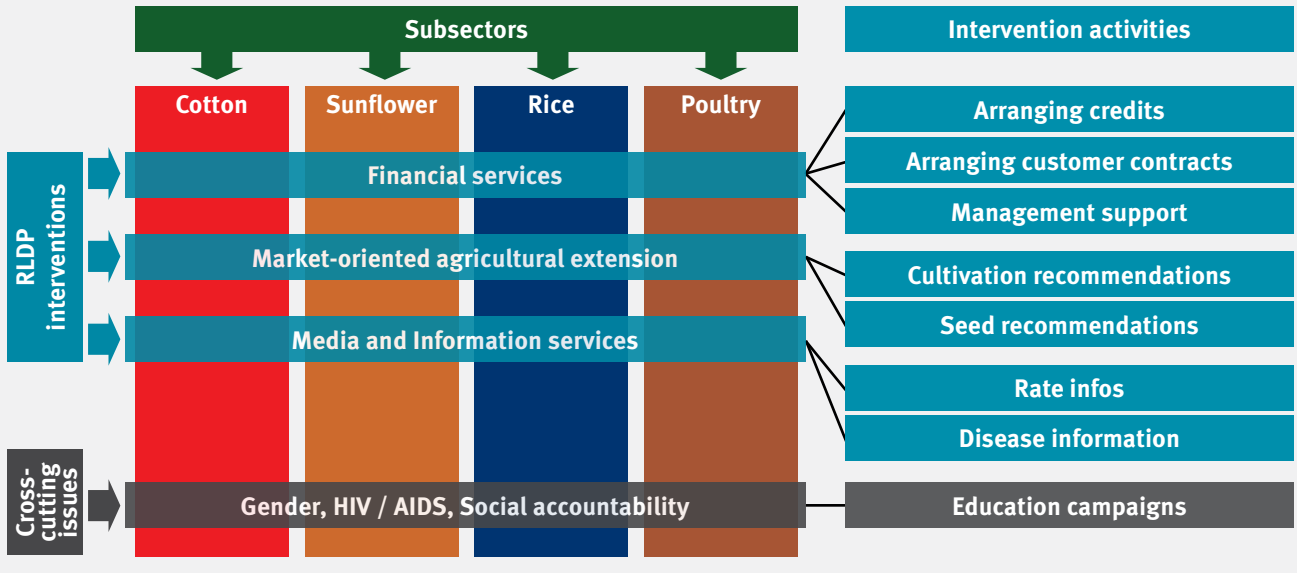
Contract farming

In order to secure the procurement of a certain crop, the system of contract farming is often adopted: both farmers and purchasers conclude an agreement in which the obligations of both partners are defined: on the one hand, the conditions for the production of a crop (quality, quantity, production technology, prices, delivery terms, etc.); on the other hand, the obligation of the buyer to purchase the products (sometimes at a predetermined price), to support production through the supply of farm input and land preparation, and to provide technical advice, etc.

The cotton sector

Cotton is the second largest agricultural export product in Tanzania. As a cash crop, it represents a major source of income and employment, offering economic opportunities to 500,000 households. Most producers are smallholders who own less than ten acres. In the 1980s, the region of the Central Corridor (Morogoro – Dodoma – Sin-

MSD approach as applied in the RLDP: the agricultural value chains (cotton, sunflower, rice and poultry) are supported with different intervention activities. Moreover, cross-cutting themes are addressed specifically.



gida – Shinyanga) contributed up to 40 per cent of Tanzania's cotton, but then a strong decrease of production occurred. A careful analysis of the situation through RLDP identified two detrimental causes. The first problem was cheating by buying agents who used tampered weighing scales. It is said that farmers lost up to 60 per cent of what should have been paid. The peasants in turn tried to influence the weight in their favour by adding sand, water and salt to their products to increase the weight.

As a consequence of these practices, everyone was losing. In order to turn this loss-loss situation into a win-win one, RLDP together with the authorities established a village cotton development committee. This committee has the responsibility to check the weight and quality of a farmer's products before he goes to a buyer. The producers now know the exact weight, and the buyer knows that he is getting good quality. This in turn makes the cultivation of cotton more interesting for farmers because they know that they are not depending on some extortionate middlemen. RLDP developed several types of interventions to address constraints and to generate opportunities to benefit stakeholders such as promoting contract farming systems, gaining better access to improved advisory services, or strengthening farmers' organisations in order to enhance capacities to collaborate with public and private actors. The improvement of agronomic practices and the use of quality seeds have reasonably increased the yields from 500 kg up to 750 kg per acre.

Need for action

The MSD approach is a potent tool to influence local and regional markets. While interventions have achieved improvements in stakeholder relationships and livelihoods of individual actors, changes are hard to achieve at a systemic level. Especially in a region with many donor activities, it is difficult to explain the role of a market facilitator such as the RLDP. Rather than seeing the RLDP as a source of advice, information and technical support, RLDP is much more easily assumed to be "another ordinary donor" who provides additional funds to run activities that increase business. Addressing gender issues is a third challenge. On the one hand, there is the problem of mainstreaming gender in the RLDP interventions, e.g. with commercial partners not having gender issues as a priority in their commercial relations. On the other, the impact of activities must be carefully observed in order to identify wrong trends early enough, e.g. when women do much of the work whereas the use of the revenue is decided outside their control and hinders spending on aspects conducive to poverty reduction, such as health and education.

The poorest, e.g. the landless, may only benefit indirectly, for instance via job creation caused by the higher turnover in a market system. Furthermore, not every smallholder is automatically a small entrepreneur. To reach a substantial number of farmers, scaling-up requires working with large purchasers. At the beginning, it may be somewhat disturbing or even distressing for a project designed to assist the poor to work with profit-oriented companies, but their extended network of partners can be extremely useful, and they are part of the market. Private companies have to realise that it is in their interest to invest in their businesses instead of simply purchasing products from the farmers.

The Market Systems Development (MSD) approach tries to identify the constraints within a value chain and to recognise the reasons why a market is not functioning properly.
Photo: P. Monteil

A girl who has shown symptoms of Ebola walks through her village to a truck waiting to take her to a hospital, in Dandano, Guinea.
Photo: S. Aranda/NYT/Redux/laif

The impact of Ebola on food security in West Africa

Not only has the Ebola epidemic cost many people's lives. It also bears far-reaching consequences for the economies of the countries affected. Around a quarter more of the people are now affected by food insecurity than before the epidemic. This above all applies to the rural population, as the following evaluation of the situation shows.

Three West African countries, Liberia, Sierra Leone and Guinea (the so-called Mano River Region) have been hard hit by the outbreak of the human disease of Ebola, at the top of the agenda since July 2014. The losses of lives, the suffering of the people who came under quarantine, and the grief and crisis for the dependent family members are just one aspect of the emergency. The other aspect is its economic impact on the societies already under extreme stress. Everyone in these countries was affected by the shocks of a war-like situation. The main repercussion derives from aversion behaviour driven by a fear of contagion. These behavioural effects impact factor and commodity markets, labour input and production, and people's livelihoods, and they have retarded economic growth.

All three West African nations are already poor, and they belong to the ten countries of the world with the lowest Human Development Index (HDI) (see Table on page 42, line 5). The Ebola outbreak makes them even poorer and people's lives even more devastated. Sierra Leone and Liberia have both emerged from horrific civil wars. Their societies enjoyed high economic growth rates in pre-crisis times. Many good efforts to regain a functioning infrastructure and economy have been crippled.

In order to estimate the impact of the disease, the UN Food and Agriculture Organization (FAO) and the World Food Programme (WFP), in collaboration with the governments and other partners, have actively carried out Rapid Assessments with field studies. Their collected figures have been inserted into an econometric model of Disease Impact on Agriculture Simulation (DIAS), a model developed by the FAO. It has been supplemented by the results of the WFP Shock Impact Simulation Model (SISMod-Light). These two sources have provided most of the figures in this article.

The societal dimension

To quarantine the virus in the epicentres of the disease, the governments introduced road blocks manned by police and military, preventing the movement of farmers and labourers,

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Some facts about the three most affected countries

	Liberia	Sierra Leone	Guinea
1. Population (July 2015 projected; million)	4.0	6.5	10.9
2. Share of agriculture to GNP	39 %	57 %	20 %
3. Share of agriculture to employment	59.6 %	66 %	84 %
4. Per capita GNP	878 USD	1,927 USD	1,255 USD
5. Rank in Human Development Index (HDI)	175	177	179

as well as the supply of goods. Côte d'Ivoire and Senegal have imposed restrictions on the movement of people and goods, including border closures. Most airlines stopped their connections to the Mano River Region. Traders withdrew from linking farmers to the markets. The food markets in towns and even in rural areas ran down to a minuscule of normal supply for many months. Some temporary market closures took place by government in most affected areas to prevent crowds from meeting. Rural inhabitants of the most affected areas abandoned their farms and villages to escape the threat of infection. Banks and shops reduced their opening hours drastically to minimise contact with clients. In the very important mining sector, on the rubber plantations and with other export sectors, work was disrupted because labourers feared to mingle with others. Ministries and public offices stopped working. The schools and universities suspended operation for more than six months. There was no business as usual any more in public life. Drastic income reductions, limited opportunities for petty business and price inflations for food on the markets had a general effect on people's livelihoods.

Economic drawback in an already very poor region

Fiscal revenues declined by the magnitude of 4.7 per cent of GNP in Liberia and 1.8 per cent in Guinea and Sierra Leone each, as predicted by the World Bank. In 2013, before the outbreak, the economic growth rates were substantial, ranking Sierra Leone second and Liberia sixth among the top ten countries with the highest GDP growth in the world (albeit starting off with very low GDP base levels). The International Monetary Fund (IMF) had forecasted that GDP growth in 2014 would amount to 11.3 per cent, 5.9 per cent and 4.5 per cent for Sierra Leone, Liberia and Guinea respectively. In mid-August 2014, the IMF revised these estimates to 8.0 per cent, 2.5 per cent and 2.4 per cent accordingly. In absolute figures, these losses amount to 1.6 billion USD as foregone GNP for the three countries. Of the losses, the World Bank estimates that 500 million USD is directly attributable to eroded consumer and investor confidence and the disruption of mobility because of the epidemic.

Impact on food security

Two factors came together that aggregated the impact of the crisis on food security. First, the timing. The outbreak of July/August 2014 happened in the peak season of agricultural planting, leaving fields unfarmed and the crops neglected. Liberia was most affected by this. Second, the regional epicentres of the disease happened to be some of the "grain baskets" of Liberia (Lofa and Margibi District; production decreased here in these months by 25 %), in Sierra Leone (Kailahun and Kenema, minus 10 to 25 %) and in Guinea (Guéckédou and N'zérékore: minus 8.5 %) (FAO). Overall, the rice harvest of October/November 2014 was about eight to twelve per cent less than in the previous years.

The shortfalls of the countries' own cereals led to a rise in food prices in Liberia, but not so much in Sierra Leone, in the second half of 2014. In many markets the prices surged by 40 per cent. The breakdown of trade and transport was the main reason for this inflation. The FAO explains the lower yields by people's fear of Ebola. Their insecurity about the transmission of the disease paralysed activities. This is true for farmers failing to go to the fieldwork and for the middlemen failing to deliver their trading services to the villages. The traditional community-based cooperative group work of the "Kuu"-system in Liberia, which carries out brushing and cleaning of agricultural plots, broke down completely. Yields decreased because agricultural inputs were hardly applied anymore, since credit availability had been significantly restricted.

Liberia is highly dependent on food imports, with a self-sufficiency of cereals of only 20 per cent (see Table on page 43, line 8). The import capacity suffered considerably by the reduction of the export capacities through Ebola (mining and agriculture), and by the depreciation of the domestic currencies. The estimated additional import needs of cereals (see Table on page 43, line 9) cannot be covered under normal commercial terms, with people lacking purchasing power. The necessary imports require international assistance, either as ODA, as credits or as physical food aid, mainly for free distribution to the most affected people. A voucher system for administrating entitlements would be needed.

As one of the poorest areas of the world, the Mano River Region (see Table above, lines 4 and 5) has always been characterised by substantial numbers of severely food insecure people. The number of hungry has been inflated by an estimated quarter through the impact of Ebola. Surprisingly, most of the additional severely food insecure people live in rural areas (see Table on page 43, line 7). The number of people vulnerable to food insecurity in Liberia was an estimated 1.1 million in March 2015; in Sierra Leone, the respective number was 2.1 million, and in Guinea 2.9 million. (People with a level of calorie intake of less than 1,799 Kcal/day are "severely insecure", while those with levels between 1,800 and 2,099 Kcal daily intake are just (moderately) "food insecure". The borderline is 2,100 – 2,399 Kcal.)

The economic impact of Ebola

	Liberia	Sierra Leone	Guinea
1. Estimated GNP loss by Ebola (mil. USD)[1)]	180	920	540
2. Estimated reduction of GNP growth rate by Ebola[1)] (with remaining growth rates for 2015)[2)]	3.8 % (3 %)	6.9 % (2 %)	4.1 % (0.2 %)
3. Reduction of cereal production 2014 in relation to 2013	8 % (from 323,000 t)	Ø 5-8 % (from 2.8 mil. t)	Ø 3-8.5 % (from 3.04 mil. t)
4. Need to import additional cereal because of Ebola	65,000 t	55,000 t	44,000 t
5. Severely food insecure inhabitants in pre-crisis times (and their share of the population)	460,000 (14 % of all)	450,000 (7.5 % of all)	970,00 (9 % of all)
6. Additional food insecure people because of Ebola (March 2015)	290,000 (63 % increase)	280,000 (62 % increase)	470,000 (48 % increase)
7. Share of rural food insecure people because of Ebola	76 %	76 %	90 %
8. National self-sufficiency rate in food	20 %	85 %	85 %
9. Cereal import requirements 2015	445,000 (24 % more)	300,000	440,000
10. Need for food assistance from outside 2015 (in tonnage of cereals)	90,000	55,000	44,000
11. No. of documented Ebola cases (April 2015)	10,042	12,201	3,548
12. No. of Ebola deaths (April 2015)[4)]	4,486	3,857	2,346

1) http://www.un.org/apps/news/story.asp?NewsID=49847#.VTC4QJMRRxI
2) World Bank; these figures do not correspond with those of the IMF
3) FAO reports (cassava is included in terms of cereal equivalent)
4) http://apps.who.int/ebola/current-situation/ebola-situation-report-15-april-2015

From emergency to recovery

Since the beginning of 2015, it seems that the virus infections have been stalled. With increased awareness on Ebola, over time, people are losing their worst agony. Markets have reopened, and trade is showing signs of recovery. However, food insecurity still remains much higher than normal, since households were not yet able to replenish their food stocks for the May/June lean season. An FAO report indicates that over 1.2 million people in these three countries need immediate assistance to reduce acute malnutrition. Economic recovery will take time, and many families will still face problems as a result of the disease for long to come.

After re-opening in March 2015, all schools in Liberia are required to set up a body temperature check for all students and visitors.
Photo: K. Hiromi/Polaris/laif

Imprint

Rural 21 –
The International Journal for Rural Development

Published by:
DLG-Verlag GmbH
Frankfurt, Germany

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60489 Frankfurt, Germany

Design:
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Design & Layout:
Andrea Trapani, DLG-Verlag

Printed by:
Brühlsche Universitäts-druckerei GmbH & Co KG
35396 Gießen, Germany

Rural 21 is published four times per year.
The subscription rate is 33.– Euro (Germany), 37.– Euro (EU countries), 51.– Euro (non-EU countries) and 8.30 Euro per issue, plus postage.

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