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).

Brian G. Sims
Consultant
Engineering for Development
Bedford, United Kingdom
www.engineering4development.co.uk

Josef Kienzle
Agricultural engineer and small mechanisation expert, Plant Production and Protection Division
Food and Agriculture Organization of the United Nations (FAO)
Rome, Italy
Josef.Kienzle@fao.org

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 conservation 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

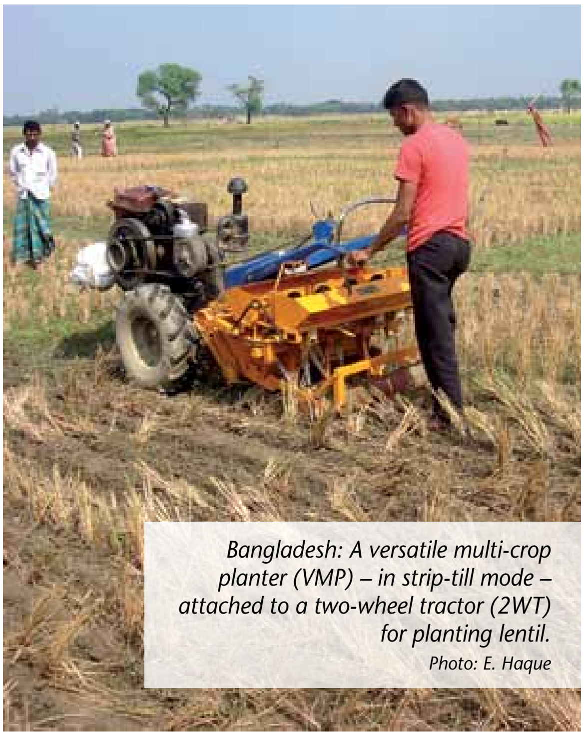
The power sources for developing country agriculture are human and draught animal muscles, internal combustion engines and electric motors. The use of the different sources varies across regions (see table). Generally engine power is on the increase, whilst draught animals are tending to decline in numbers, 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**