RURAL 21

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Plant breeding for food security

Photo: Jörg Böthling

RURAL DEVELOPMENT IN AFRICA
German NGOs on the right track?

FAMILY FARMING
Challenges, prospects and the role of transformation

NUTRITION
How 'supermarketisation' affects diets and health in Kenya

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DEAR READER,

You will certainly be surprised when you hold this edition of Rural 21 in your hands – two titles and two focal areas. This is really new, and the story behind it is that the two topics concerned were postponed from one editorial conference to another only to be discarded each time – the reason being that they were indeed relevant and of considerable importance to food security in the Global South but did not happen to be "burning issues".

For this section of the current edition, we asked specialists from international agricultural research centres to give accounts of their activities in plant breeding. This had been prompted by the ruling of the European Court of Justice in late July 2018 stipulating that new plant breeding technologies such as genome editing receive the same legal treatment as conventional genetic engineering methods do. While this does not ban their application (in Europe), they are now subject to stringent regulatory conditions. In response to this development, leading scientists from more than 85 European plant and life science research centres issued a position paper warning that the ruling was "irresponsible in the face of the world's current far-reaching agricultural challenges".

This edition of Rural 21 is by no means intended to once again spark the old debate on the pros and cons of genetic engineering – the arguments here are by and large well familiar, and positions regarding the issue are more or less firmly established. Rather, what we want to show is which developments plant breeding has seen over the last few decades and what challenges it faces today given climate change and more and more global crises. Our authors from the International Maize and Wheat Improvement Center in Mexico and from the International Rice Research Institute in the Philippines provide a brief history of the field and present its various approaches and technologies. With an account of work on breeding New Rice for Africa – Nerica – varieties, our authors from AfricaRice show how crucial involving farmers in the breeding process is and how this can be practically implemented. And our author from Wageningen University, in the Netherlands, takes a look at what the implications of European legislation could be for African agriculture – even if it cannot obtain legal force there.

This edition also includes a critical review of attitudes among German non-governmental organisations towards rural development in Africa, a favourable look at the UN Decade of Family Farming and a scientific view of the link between shopping behaviour, nutrition and health.

We wish you inspiring reading.

Sincerely yours,

Silvia Richter

Imprint

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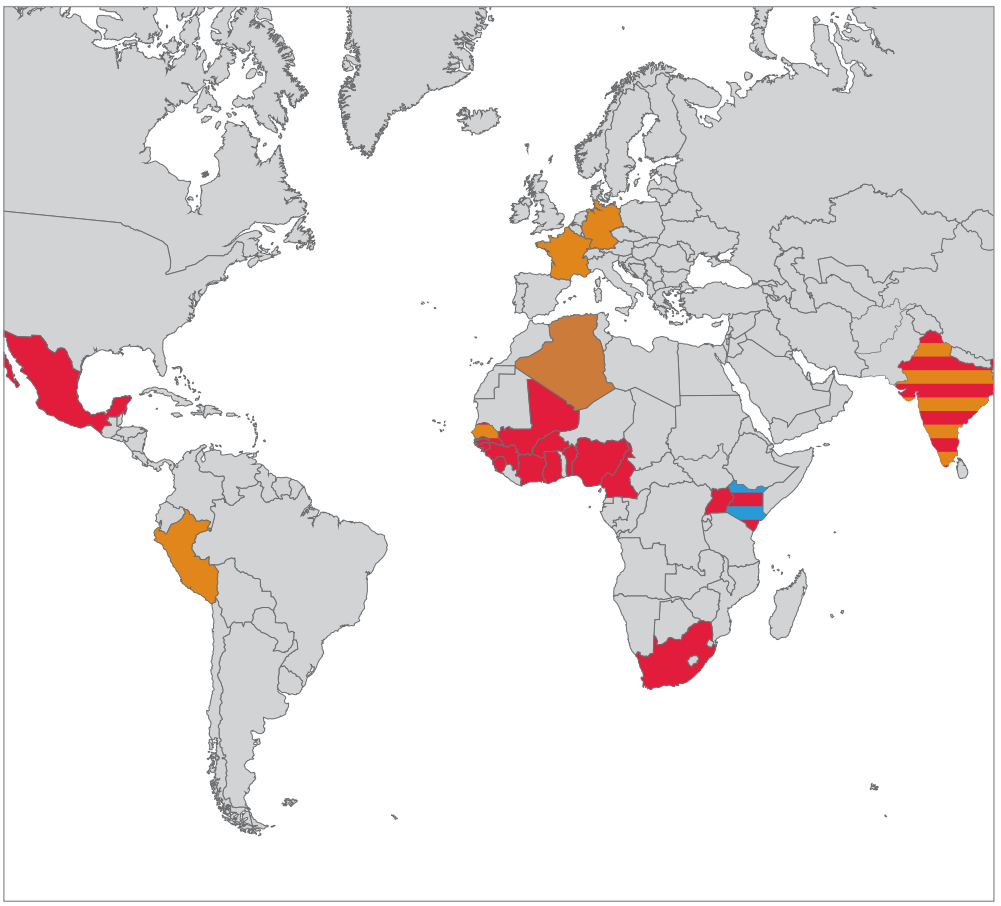
NEWS

FOCUS

OPINION

SCIENTIFIC WORLD



4TH WORLD CONGRESS ON AGROFORESTRY

The 4th World Congress on Agroforestry organised by the French Agricultural Research Centre for International Development (CIRAD) and the French National Institute of Agricultural Research (INRA), in partnership with World Agroforestry (ICRAF), Agropolis International and Montpellier University of Excellence, was held in Montpellier, France, in late May 2019. Around 1,200 delegates from 100 countries called for a transformative change to tackle the impacts on the planet of the global food system.

The Montpellier Declaration agreed by the delegates states that the degradation of the world's biodiversity documented in the recent report by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) is principally due to poor agricultural practices. Many presentations at the Congress noted that adding trees to crop fields and pastures delivered on biodiversity, while maintaining or enhancing food security and nutrition. In addition, it they stressed that it often led to increased farm profitability and helped mitigate and adapt to climate change, while optimising water management and restoring soils. The delegates welcomed that

Cartoon: Julien Revenue

farmers around the world were beginning to recognise the importance of trees in their production systems, yet noted with concern that progress was still spotty and slow. They further stated that agroforestry systems were usually profitable systems. What was costly was the agroforestry transition, which took time and which had to be supported. The delegates noted that in the long term, the cost of transforming land use patterns to make them compatible with planetary health was either low or negative.

For Diaminatou Sanogo, Director of the National Centre for Forestry Research of Senegal's Agricultural Research Institute, enabling policies were essential. "The President of Senegal recently expressed the need for a transition to agro-ecology and asked agencies to develop new approaches," Sanogo reported. "Agroforestry can contribute to agro-ecological intensification and climate resilience." Sanogo's research group won an award in the climate change category. According to their findings, using native tree species allows yield increases while largely reducing fertiliser use and thus contributing to food security and resilience for farmers in the groundnut region of Senegal. (db)

GLOBAL NDC CONFERENCE

Focusing on "Inspiring action and enabling change", the Nationally Determined Contributions Conference was held in Berlin/Germany from the 12th to the 14th June 2019. Roughly 300 delegates from more than 80 countries discussed and shared approaches to implement their Nationally Determined Contributions (NDCs) to achieving the Paris Agreement while tackling climate change through integrating mitigation and adaptation measures in their national strategies.

In 2015, at the COP21 held in France, the Paris Agreement was communicated, in which all countries, including developing countries for the first time, had to set their own NDCs. In 2018, at the COP24 in Poland, the Katowice climate package – also known as the rule book of the Paris Agreement – was adopted. This rule book focuses on the implementation of the NDCs. Bernd Hackmann, Programme Officer for the Mitigation, Data and Analysis Programme of the United Nations' Framework Convention on Climate Change (UNFCCC) Secretariat described the role of the Convention in assisting the governments to achieve the NDCs. "The Paris Agreement is much more than the NDCs, but the NDCs are its core," Hackmann said. The Paris Agreement establishes a mandatory NDC process which implies a first submission by 2020 and an enhanced ambition submitted every five years thereafter. The Agreement builds on aggregate and individual progression and countries' ambitions. According to Hackmann, the Talanoa Dialogue and the global stocktake as well as the Transparency Framework serve as feedback mechanisms throughout the process, which means that every government has to report on its progress with regard to achieving the NDCs.

FROM CLIMATE NEGOTIATIONS TO CLIMATE IMPLEMENTATION

Peru's five lines of work were presented by Rosa Morales, General Director of Climate Change and Desertification of the Ministry of Environment in Peru. They comprise paving the way for 61 mitigation measures and 91 measures of adaptation, setting up institutional arrangements, putting climate change laws and rules in place, considering indigenous peoples, starting multi-sectoral work with sub-regional governments, which only exists at central level so far, as well as mobilising finance.

Sandra Motshwanedi, Deputy Director of International Reporting on Climate Change at South Africa's Department of Environmental Affairs, said that her country had introduced a carbon tax which entered into force in June this year. In addition, South Africa had formulated a national energy strategy. "We prepared a National Inventory Report to determine energy emissions particularly of coal and of aluminium production. The year 2000 serves as a base for our time series until 2015. And so we provide transparency through a Monitoring, Reporting and Verification (MRV) system which is estimating emissions," Motshwanedi

explained. "Thus we know if we are on track. This enables us to analyse what is not working in our policy framework and how to improve it."

Mukund Kumar Sinha, Joint Secretary and Officer on Special Duty and Director General of the Government of India's Institute of Urban Transport, Ministry of Housing and Urban Affairs, said that his country had started to formulate climate change policies. One of the mitigation intervention targets was to produce 100 gigawatts of solar energy by 2020. Current solar energy production was at only 23 gigawatts. Another measure related to adaptation was a programme to start national electric mobility. The remaining challenges were creating structures for charging. "The economic development imperative is that we have to move very fast because of globalisation. There are aspirations which have to be balanced with ongoing progress," Kumar Sinha said.

According to Kumar Sinha, India developed a framework for development and transport which takes all emissions into account. "In terms of climate change, everybody is a stakeholder. When questions arise such as what a sustainable transport system has to look like, engaging citizens is a part of the planning and implementation process in the country," Kumar Sinha said. South Africa is counting on ownership of the actors in the different sectors. Before a regulation was to be endorsed by the government, a stakeholder consultation process would take place, Motshwanedi said. A reporting regulation on greenhouse gas emissions including guidelines on how to report was already in place, she continued. "The narrative that we use when we talk to stakeholders, we ourselves have to be informed, to be able to inform the regional government," Morales noted. In cooperation with regional governments, regional climate change strategies were being formulated and a roadmap had been set up explaining mitigation and adaptation measures for civil society. Also, indigenous people could be involved in the national system of forest monitoring through taking care of specific measurements, said Morales.

WHAT NEXT?

While almost all decisions adopted at COP24 are relevant for NDCs, further guidance in relation to the mitigation section of decision-making and on the adaptation of communication, modalities and procedures and guidelines for the transparency framework (tracking on progress) is needed. According to Hackmann, this applies especially in terms of what an NDC has to look like and how to formulate and implement it.

Another remaining question is how to engage the ministries of finance in meeting the Paris Agreement. "If we don't have them on board all over the world, the challenge will be huge," stated Morales.

The conference contributes to the preparation of this year's UN Climate Summit taking place in New York on the 23rd of September 2019. (db)

DOING JUSTICE TO THE OCEANS

Overfishing and deep sea mining, rising sea levels and plastic waste – competition for the marine natural resources and the impacts of global commodity flows are putting increasing pressure on the marine ecosystem. It was this aspect, together with the 25th anniversary of the United Nations Convention on the Law of the Sea, UNCLOS, that prompted the organisations Forum Environment and Development, Fair Oceans and Bread for the World to discuss the difficult balance between using and protecting the marine ecosystem in the run-up to World Oceans Day, the 8th June, in Berlin, Germany.

"Presently, global warming is the chief driver of changes in the oceans," Hans-Otto Pörtner, a scientist at the Alfred Wegener Institute in Potsdam/Germany, said opening the event. Using various climate scenarios, he demonstrated the impacts of the "deadly trio" of warming, acidification and lack of oxygen in the oceans: the dying of warm water coral reefs, changes in the Jetstream resulting in extreme weather events, the compression of habitats for fish … "If we do not succeed in limiting global warming to a maximum of 1.5 degrees Celsius, we won't be able to achieve SDG 14," Pörtner warned. Drastic reductions in emissions – not only of CO_2, but also of methane, nitrogen oxides and soot – were just as vital as stopping subsidies for fossil energy sources and a general reallocation of investments in the energy sector.

Artisanal – and usually coastal – fishery accounts for 21 per cent of around 80 million tons of fish fetched from the sea annually by the roughly 270 million fishers in capture fishery. In addition to the pollution of the seas and the building of ports, with their negative impacts on coastal ecosystems, small-scale fishers in the Global South are above all under pressure from distant water fisheries, and also owing to the fact that more and more fishers are seeking a good catch with more and more effective material and equipment. The West African nation of Senegal, for instance, had three million inhabitants in 1960, and now has 15 million, while the number of boats has increased threefold over the last 15 years. "But one can't generally speak of an overfishing of the seas," said Werner Ekau of the Leibniz Centre for Tropical Marine Research (ZMT). "Just like in Senegal, overfishing is often a regional or species-specific problem." Frequently, small stocks were affected, whereas large, well-monitored stocks – such as herring or cod – were not presenting any problems.

Ekau maintained that training fishers and better information for fishery cooperatives, e.g. on spawning seasons and locations of various species, were essential, for instance so that they could protect certain areas over certain periods. "But the most important aspect is better policies," the marine expert stressed. "We need rules and monitoring." Fishing licences were often awarded to clans and families, while individual small fishers were left empty-handed.

It would not be possible to conserve the marine resources in the long term without designating protected areas, the participants of the event agreed on. But protecting and using the seas need not be mutually exclusive. Regarding food sovereignty and the human rights-based approach, Carsten Pedersen of the Transnational Institute recommended that fishers be integrated in designating marine protected areas (MPAs) right from the start. Frequently, however, the organisations involved focused on an ecocentric approach. There had been a mere five fishers among the 1,500 participants in the recent conference of the International Union for the Conservation of Nature (IUCN) on MPAs. "We cannot come with our Northern ideas and tell people what they have to do," Pedersen maintained. (sri)

Modern crop breeding began around 1900. – Tigist Masresra, a technical assistant, working in the Highland Maize Breeding Program at Ambo Research Center, Ethiopia.
Photo: CIMMYT/ Peter Lowe

HOW PLANT BREEDING HELPS TO FEED THE WORLD

Farmers already started to modify plants physically and genetically in order to achieve better yields several thousand years ago. The Director-General of the International Maize and Wheat Improvement Center (Cimmyt) shows how demands on plant breeding have changed over the last four decades and which methods the international research community is developing to master present and future challenges.

By Martin Kropff

Breeding of maize and wheat was begun by early farmers as part of their domestication of naturally-occurring grass species, to better feed their families and communities. Maize comes from a wild ancestor known as teosinte that still grows in Mexico and which farmers began to use at least 7,000 years ago. Bread wheat resulted from natural crosses between emmer wheat and goat grass, likely in the Northern Caspian Sea area some 12,000 years ago. Farmers modified these proto-crops physically and genetically by selecting for bigger grain, better yields, spikes that stayed together rather than dropping seeds, and other qualities of interest.

Modern crop breeding began around 1900, with the rediscovery of Gregor Mendel's laws regarding genetics and inheritance, together with the emergence of formal agricultural research systems in many of today's high-income countries. One key outcome was the development of hybrid maize in the early 1900s; its rapid adoption in the 1930s created much excitement about the potential of genetics to revolutionise agriculture.

HUNGER ALLEVIATION AND DEVELOPMENT – A HISTORICAL CONTEXT

The world food problem has been an ongoing debate at least since Thomas Malthus' book, *An Essay on the Principles of Population*, brought the issue to the fore in 1798, suggesting that population growth inevitably leads to famine. At the dawn of the 20th century, continued discussion on the topic included books such as *The Wheat Problem*, published by distinguished British scientist Sir William Crookes in 1898. The Great Depression of the 1930s severely curtailed demand and led to a global grain glut, but also fuelled a growing awareness that much of the world lacked sufficient food. A seminal paper presented at the League of Nations in 1935 by Frank McDougall, Australian farmer and self-trained economist, and Stanley Bruce, ex-prime minister of Australia, argued for increasing agricultural production to meet the world's nutritional needs. McDougall helped influence US President Franklin Roosevelt to request the first UN conference on world food issues in 1943. Following World War II, acute food shortages in China, Europe, Japan and other countries brought world food and hunger to humanity's attention.

Finally, Cold War politics set in motion a big push for development aid, technical assistance, and food aid from about 1950 on. Dominating discussions of world food security at the time was the sharp rise in population growth in the developing world during 1940-60, driven in part by the Second World War's end and better health, sanitation and control of disease epidemics. Books of the time, including Paul Ehrlich's *Population Bomb*, reflected a revived Malthusian pessimism.

THE GREEN REVOLUTION – A SUCCESSFUL EXAMPLE OF AGRICULTURAL DEVELOPMENT

Against this backdrop, in 1940, US Vice President Henry Wallace, founder of the Pioneer Hi-Bred maize seed company, attended the inauguration of the new Mexican President, Ávila Camacho, and was asked by the country's Minister of Agriculture, Marte R. Gómez, to provide technical assistance to help erase the country's deficit in maize, wheat and bean production. Upon his return, Wallace approached the Rockefeller Foundation for assistance in addressing Mexico's request. With Mexico's support, the Foundation established the Office of Special Studies (OSS) in Mexico in 1943. The following year, young U.S. scientist Norman E. Borlaug joined the team of international experts at the OSS, eventually taking charge of research on wheat.

His work featured several major scientific achievements. Strong resistance to stem rust, a disease that was ravaging Mexican wheat-growing areas, was the first breeding goal. To speed progress, Borlaug found two climatically different locations to grow two generations each year, thus halving the time necessary to produce a variety. Differing in elevation by 2,600 metres and in latitude by ten degrees, the locations also exposed advancing generations of wheat to differing spectrums of diseases, environmental problems and daylengths. The wheat varieties that emerged from this system were more broadly adapted, as well as resistant to stem rust and other diseases.

To address the issue of the wheat plant falling over, known as "lodging", under the heavier grain, Borlaug crossed the Mexican wheats with a source of dwarfing genes and by the late 1950s had developed semi-dwarf wheat varieties that not only resisted lodging but had a new plant architecture in which more dry matter was apportioned to the grain. The result was a quantum leap in yield that brought Mexico self-sufficiency in wheat production.

Dr Norman E. Borlaug conducting a training course for wheat breeders at the experiment station in Ciudad Obregón, Mexico, 1963.

Photo source: unidentified

In the early 1960s, South Asia was facing mass starvation and extreme food insecurity. To combat this challenge, scientists and governments in the region began assessing the value of the Mexican semi-dwarf wheat varieties for their countries. Trials in India and Pakistan, based largely on professional contacts established by Borlaug who had been visiting the region since 1960, were convincing and demonstrated high yields that offered the potential for a dramatic breakthrough in wheat production. Founded in Mexico in 1966, the International Maize and Wheat Improvement Center (Cimmyt) had emerged directly from and amalgamated many programmes and professionals from the Office of Special Studies and similar regional collaborations on the two crops. When harvests in South Asia fell drastically short for two years in a row, threatening famine, Borlaug, who was leading Cimmyt wheat research, organised in 1966 a shipment to India of 18,000 tons of the semi-dwarf Mexican wheat seed and, in 1967, 42,000 tons were shipped to Pakistan.

In combination with appropriate fertilisation and management practices, the new wheat varieties raised yields enormously in India and Pakistan. By 1969, Pakistan was self-sufficient in wheat, and India had boosted national wheat production to the unprecedented level of 17 million tons. These successes gave impetus to local breeding programmes and to changes in government policy that favoured agriculture. Other wheat-producing countries began to follow suit and the spreading revolution in agriculture benefitted millions of farmers and consumers. Together with the development and spread of improved rice and maize varieties and farming practices, the phenomenon was called the "Green Revolution".

Upon receiving the 1970 Nobel Peace Prize for his contributions to the Green Revolution, Borlaug cautioned that the achievements were temporary measures to buy time for governments to address exploding world populations and associated problems. Critics of the Green Revolution have cited the environmental consequences of intensive cultivation, including soil degradation, chemical pollution, aquifer depletion, and soil salinity, as well as of the differential socioeconomic impacts of the new technologies. Notwithstanding, it is unclear what alternative scenario would have allowed developing countries to meet the human needs posed by the massive population expansion of the 20th century, and without triggering more deforestation. At the same time, greater awareness about environmental impact and constraints has shifted the focus of research towards sustainable approaches, in the decades following the early Green Revolution.

THE GLOBAL FOOD SYSTEM UNDER PRESSURE

After declining for nearly a decade to around 770 million, the number of hungry people – those who fail to get enough calories for healthy and productive lives and essentially go to bed hungry at night – has increased in the last three years to more than 850 million. Intensified and widespread conflicts and migration have contributed significantly to hunger, but rising temperatures, more frequent droughts and flooding, and evolving and spreading crop diseases and pests are ruining harvests, intensifying farmers' risks and reducing local and global food security.

A landmark 2015 study by the insurance market Lloyds's of London showed that the global food system is under significant pressure from potential, coinciding shocks, such as bad weather combined with crop disease outbreaks. Other research has demonstrated that, for wheat, the declining area sown world-wide, together with massive stockpiling by China, which is the world's number-one wheat producer but is not exporting surplus wheat, is masking significant risk in global markets. A drought or serious pest or disease outbreak in a key wheat-growing country could tighten markets, reducing access to grain and leading to price spikes that most sorely affect the poor, who spend much of their income simply to eat each day.

A Cimmyt field worker demonstrating the emasculation of a wheat spike at Cimmyt Headquarters.

Photo: CIMMYT/ Alfonso Cortes

For example, the number-one food crop in sub-Saharan Africa, maize, has been under siege over the last decade from more frequent droughts and outbreaks of new pests and diseases in the region. Among these are the deadly viral disease maize lethal necrosis and the fall armyworm, an insect pest from the Americas that appeared in Nigeria in 2016 and has since overrun the continent, gravely reducing local availability of the vital food grain.

Approaches to overcome these challenges need to be multi-sectoral and include providing access for farmers to seed of stress-tolerant, disease-resistant crops, along with inputs that ensure their productivity and sustainable, locally-suited cropping systems.

Drought-tolerant maize hybrids and varieties developed by Cimmyt and partners using conventional breeding (cross-pollination + repeated generations of intensive selection) provide a grain yield advantage of at least 25-30 per cent over non-drought tolerant varieties in sub-Saharan Africa under drought stress. This can give farmers a harvest where there is none for non-drought tolerant varieties, reducing farmers' risk of losses.

Breeding for drought tolerance and disease or insect resistance in maize involves selection for yield under carefully managed stress; that is, creating controlled drought or artificial infestations / infections on experiment station plots and selecting the plants that yield grain. Associated methodologies were pioneered, refined, and documented by Cimmyt over several decades. Through selective support for infrastructure, training, and other assistance, the organisation expanded the capacity in partner countries to screen for drought tolerance and resistance to common diseases and pests, as well as supporting the emergence of competitive, high-quality seed markets and companies to promote farmers' use of stress tolerant varieties.

The climate challenge

Agriculture and food systems account for up to 29 per cent of greenhouse gas emissions, and at the same time will be profoundly affected by the rapidly changing climate. Agriculture also accounts for about 70 per cent of water withdrawals globally.

Decades of research and application by scientists, extension workers, machinery specialists, and farmers are refining and spreading practices that conserve soil and water resources, improve yields under hotter and drier conditions, and reduce the greenhouse gas emissions and pollution associated with maize and wheat farming in Africa, Asia, and Latin America.

Supporting the sustainable intensification of farming in those regions, the practices include reducing or minimising soil disturbances such as tillage, retaining crop residues and using crop rotations – three practices known collectively as "conservation agriculture" – as well as other climate-smart farming approaches. Technologies for intensified, irrigated wheat cropping systems allow farmers to apply nitrogen fertiliser in the precise dosages and at the time needed by plants, thus reducing nitrous oxide emissions and nitrate runoff into water systems.

As is evident from the above, science can help address the complex issues facing agriculture today, but continued policy attention and investments in agricultural research for development are crucial.

Hidden hunger and malnutrition

In addition to those who eat too little, the diets of two billion persons world-wide lack essential micronutrients – Vitamin A, iron, or zinc – and this especially affects the health and development of children under five years old. An approach known as biofortification, involving the creation of micronutrient-dense staple crops using breeding, can improve nutrition as part of an integrated, food systems strategy. Cimmyt, various institutions of the Consultative Group on International Agricultural Research (GCIAR), and numerous national research organisations and scaling partners have in recent years developed and released more than 60 improved varieties of maize and wheat in 19 countries of Africa, Asia, and Latin America. Their grain features enhanced levels of the essential micronutrients zinc or pro-Vitamin A.

REAFFIRMING THE ROLE OF GLOBAL CROP BREEDING

In partnership with national institutions, international agricultural research has been extraordinarily successful in supplying world food needs, particularly considering how quickly population has grown and with the added demands of crop use for animal feed. Much of this success can be attributed to investments in the genetic improvement of crops. International collaboration in breeding and climate-smart farming practices will and must continue to be a central pillar of improving human welfare. Sustained support is required so that high-quality scientists and development specialists can continue to work across borders and offer farmers productive and environmentally-friendly technology.

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INTERFACING CONVENTIONAL AND MODERN APPROACHES TO SPEED UP AND FOCUS PLANT BREEDING

Plant breeding relies on discovering, generating, selecting and utilising genetic variation in agronomic traits. This can be achieved in many ways – and at very different speeds. Our authors present various approaches and technologies – with their strengths and weaknesses – ranging from pollination-based conventional plant breeding to the Crispr/Cas genetic scissors.

By Ajay Kohli, B.P. Mallikarjuna Swamy and Venuprasad Ramiah

The Crispr/Cas technology – represented here as a model – has already been used to modify traits such as the fruit/grain quality and quantity, nutrient content, bacterial, viral and fungal disease resistance, drought and salinity tolerance and herbicide tolerance.

Photo: Bilderbox.com

Human population grew from one billion to two billion in 123 years, but it grew from five to six billion only in 12 years (1987-1999) and also from six to seven billion in another 12 years (1999-2011). Our population is now predicted to level out at ten billion beyond 2050. Sustaining the more than seven billion people today is already a challenge with the business-as-usual scenario. The increasing numbers of people over time, and recently the growing middle classes, generate an incremental demand on natural resources, which is inconsistent with the natural supply or replenishment of these resources.

The single most important resource for survival is food. Nearly eleven per cent of Earth's surface is devoted to crop production. Yet only 3.5 per cent of it suits crop production without any problems. For the remaining 7.5 per cent, human endeavour through tools and technologies has overcome the problems to make the land good for agriculture. Similarly, making agriculture good and sufficient for humans (including their livestock) has also been possible through constantly improving technologies. One such technology, with a great capacity to feed the world, is plant breeding.

Plant breeding generates new varieties of crop plants that are much more high-yielding than the previous ones. Generating new varieties depends on generating novel or enhanced traits through genetic recombination during cross- or self-pollination (see Glossary on page 10). The efficiency of plant breeding depends on the life-cycle period of the respective crop, which can vary from a few months for grain staples (rice, wheat, maize), through a couple of years (cassava) to many years (perennial fruit trees). Hence pollination-based conventional plant breeding between limited lines undertaken by humans remains a time-consuming technology which cannot keep up with the pace at which crop improvement is required to feed the growing population. Several approaches and technologies have been invented (see Glossary on page 11) in order to hasten the generating and capturing of variations in useful traits such as increased yield or resistance to diseases.

LITTLE PLANT BREEDING GLOSSARY I: BASIC TERMS

Abiotic stress: Environmental stresses such as drought, flooding, heat, cold, salinity, etc. that affect plant productivity.
Allele: Variant form of a gene.
Biotic stress: Stresses that affect plant productivity caused by biotic factors such as microbes, insects, weeds, etc.
Cross-pollination: Refers to pollen cell of one plant fusing with the egg cell of a different plant of the same species to generate the first cell of the next generation.
DNA: Deoxyribonucleic acid (DNA) is the fundamental heredity matter in most living organisms.
Gamete: Haploid cell that fuses with another haploid cell during fertilisation in organisms that sexually reproduce.
Genetic engineering: Refers to direct manipulation of DNA of an organism to bring about a desired change in the phenotype.
Genome: The complete set of genetic material present in a cell.
Genotype: The genetic constitution of an organism.
Heterosis: Heterosis (also **hybrid vigour** or **outbreeding enhancement**) is the improved or increased function of any biological quality in a hybrid offspring.
Hexaploid: An organism with six copies of a haploid set of chromosomes (example: bread wheat).
Introgression: Introduction of a gene/ alleles from one organism to another organism by hybridisation and backcrossing.
Markers: Segments of DNA that can be easily identified to suggest that a particular trait or genomic region is present in a plant making it useful for selecting to take to the next stage.
Molecular marker: Fragment of DNA that is used as a marker to associate with a particular gene/ trait.
Nucleotide: Basic structural unit of DNA.
Phenotype: Observable physical expression of genotype.
Plant genetic resources: Plants of the same species in different eco-geographies exhibit variations in traits in line with adaptations for the particular locale. All such plants taken together form the genetic resource for the species and can be used as donor for introgression of the trait.
Polymerase chain reaction (PCR): A method to amplify specific regions of the DNA in a test tube starting with an extremely small amount of the original DNA coming from any biological source or synthetic chemistry.
Polyploidy: A condition wherein an organism/ cell will have more than two copies of its haploid set of chromosomes.
Recombination: A process by which genetic material between two chromosomes in a cell are exchanged.
Selection: The act of choosing desirable/ adaptable plants in a random population by natural forces or by human interference.
Self-pollination: Refers to a pollen cell of one plant fusing with the egg cell of the same plant to generate the first cell of the next generation.
T-DNA: A piece of its DNA transferred by a bacteria (Agrobacterium) into the plant genome, largely without bias in where it is transferred.
Transgene: Gene introduced into one species from an another species by artificial means.
Transposon: These are genetic elements that can move from one part of the genome to another within a cell.

INCREASING PRECISION IN PLANT BREEDING

Plant breeding has been said to be as much an art form as a science. 'Talking to the plant' is the phrase often used by breeders to denote regular visits to the fields to monitor growth, development and reactions to biotic and abiotic factors of a population under study. This allows selecting the desirable plant type from a multitude of plants and propagating it through generations with continuous trait selection, finally leading to a new variety. Such self- or cross-pollination-based conventional plant breeding relied on visual selection of the desired trait. Such a selection would underpin recombination at the genome level. But there was no specific control over the extent of parental gene transfer and genome scrambling. With additional breeding approaches such as backcrossing, recipient genome content could be increased. Molecular markers then allowed tracking the introgression of a trait with DNA while reconstructing most of the recipient genome. This simple method is now reaching the limits of manual handling due to the increasing number of markers, down to single nucleotide polymorphism, and the pace at which they can be scored and analysed.

As an example, marker-assisted selection (MAS) was used for developing "super rice" through already known functional alleles for grain quality and yield using three parents. However, despite the application of automated platform technologies employing numerous markers such as the simple sequence repeat (SSR) markers to perform the functions of DNA extraction, polymerase chain reaction (PCR) and downstream marker scoring and analysis, regions of the recipient genome still remain that are not fully characterised regarding the parent they belong to. To achieve that and to facilitate 'Breeding by Design', the relevant genetic information as well as the tools to use that information need to be in place. The advent of next-generation DNA/genome sequencing technologies is filling some of these technological gaps. Similarly, the technology of double-haploid (DH) plants is very useful in fixing genes in a homozygous state. DH uses in vitro culture techniques to culture haploid single cell pollen grains into diploid plants that then have an exact copy of the original set of chromosomes. The most important resource for plant breeding is the germplasm (available as accessions in respective genebanks for each crop), including the set of wild species, which are not of much use for yield prima-facie but harbour useful genes against biotic and abiotic stresses. These can be harnessed by 'wide hybridisation', which allows mating of a wild and a cultivated accession applying the biotechnological approach of embryo rescue. This enables accessing genetic variation from related species to improve the crops.

An ideal situation would be to maintain the entire genome of the recipient plant and modify it for a single or a few genes – up- or down-regulation of which could affect the trait under consideration. Genetic engineering was a step in that direction. However, it was realised that the process can also generate some changes in the region where the transgene is inserted, not to mention the need for selecting single copy insert events or obtaining marker-free plants. Despite comparatively highly improved precision and stringent regulatory processes that ensure that no unintended effects reach the consumer, this technique has had much opposition in certain regions of the world.

Point mutation through mutation breeding strategies is another approach with a promise of keeping most of the recipient genome intact. Products of mutation breeding do not undergo regulatory procedures and can be certified as organic if grown accordingly. However, it is hardly ever the case that a single mutation occurs in the gene of choice while leaving the rest of the genome unchanged. Agronomic traits are

The efficiency of plant breeding depends on the life-cycle period of the respective crop, which can vary from a few months for grain staples to many years for perennial fruit trees or shrubs, as in the case of jatropha.

Photo: Jörg Böthling

mostly regulated through complex genetic mechanisms. An apparently simple trait depends on many genes. A desirable change noticed through mutation breeding is more likely to occur through multiple changes in different genes. There are however examples of single-base mutation, cloned and characterised as such, leading to improvement in agronomic traits, e.g. the silicon uptake gene in rice.

BIOTECHNOLOGY-MEDIATED GENE/ TRAIT DISCOVERY FOR BREEDING

Progress with innovations in tools and techniques of plant biotechnology combined with ease and speed of experimentation and analysis led to the identification of a number of new genes for agronomic traits such as yield, quality, biotic and abiotic stress resistance. Generating a plant population of individuals with a single gene mutation per plant (saturation mutagenised populations) so that, collectively, potentially all the genes are mutated through T-DNA or transposon insertion in the gene was one manifestation of such tools. However, these results rarely translated into commercial products, mainly because the identified genes did not always have similar qualitative and/ or quantitative effects in other crop plants compared to the model plants (Arabidopsis, tobacco) in which the gene was identified and well characterised. Although rice has also been used as

LITTLE PLANT BREEDING GLOSSARY II: PLANT BREEDING APPROACHES AND TECHNIQUES

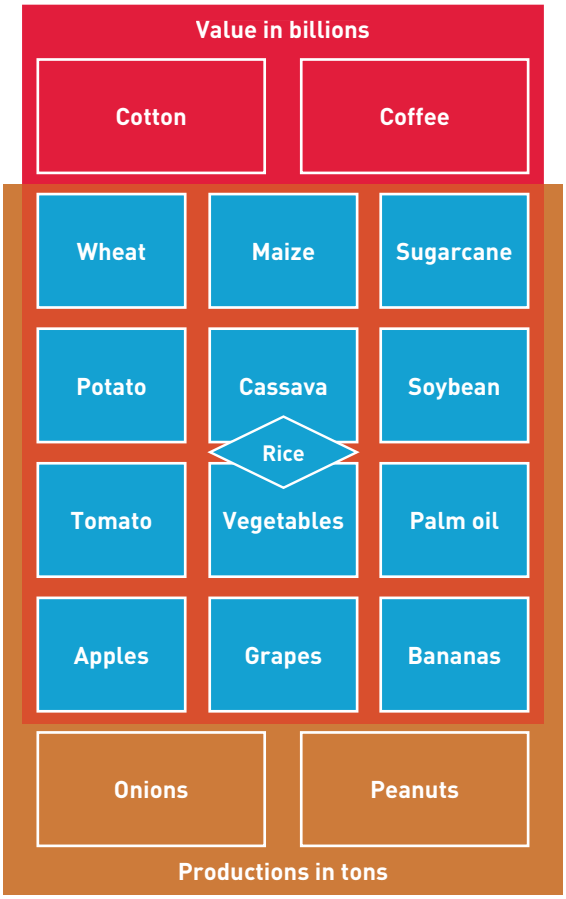
Anther culture: A technique by which plants are regenerated from anthers, the pollen-producing parts of flowers.
Backcrossing: Crossing in which an offspring is mated to one of its parent.
Biotechnology: Molecular markers for traits highly facilitated plant breeding by fast-tracking selection for a trait. Starting from protein isozyme markers, the DNA markers and their sequentially growing speed of analysis up to the single base revolutionised plant breeding, while genetic engineering became a branch for plant breeding in its own right.
Crispr/Cas: A method in which DNA can be cut and changed in a targeted manner. Single DNA building blocks can be inserted, removed or switched off.
Genome Editing: Genetic engineering technology wherein genetic information at specific sites is altered.
Embryo rescue: An in vitro technique to rescue a failing embryo to generate a complete plant.
Epistasis: Genetic interactions between two or more genes affecting a trait.
Heterosis: Plants belonging to the same species but genetically rather diverse exhibit the tendency of improved agronomic traits including yield, quality and resistance to biotic and abiotic stresses. The molecular underpinning of the phenomena is still unclear, but it has been heavily used in maize and rice breeding.
Mutation breeding: Chemical (ethyl methanesulfonate, EMS) and physical (radiations such as gamma rays) agents generate mutations, some of which can be useful and thus harnessed in improving plants.
Polyploidy: Induction of polyploidy can be helpful in wide hybridisations and thus becomes a useful approach in combining traits from parents that would normally not cross-fertilise.
Point mutation: Mutation wherein a single nucleotide change has occurred.
Tissue culture: The first laboratory-based technology for breeding, later subsumed into biotechnology, allowed in vitro culture and regeneration of new plants from different organs through cellular totipotency through which potentially any plant cell can give rise to a full plant.
Wide hybridisation: Crossing of plants may not be limited to individuals within a species. In rare cases, fertilisations between different species of the genera are possible, including wild species, and this increases the breadth of donors for useful traits.

CoMoPheno* breeding: This is the latest approach, whereby high-throughput molecular marker and phenotype analysis supports conventional breeding and the approach capitalises on biotechnology-based molecular physiological understanding of plants for trait discovery and gene discovery, which in turn facilitates the modern GM free breeding approach through the Crispr systems.

* We have used this term coinage and its definition here for the first time as we believe that such interfacing of tools, techniques and approaches holds the future to fast tracking plant breeding by overcoming life-cycle timeline limitations leading to new plant varieties much more quickly. It denotes **Co**nventional **Mo**lecular and high-throughput **Pheno**typing-based breeding. CoMo in Latin means 'bring together', thus the bringing together of the phenotype data on a large scale in much less time for breeding.

a model cereal for such studies and some successes cross over from rice to other cereals, frustratingly, rice genes characterised in one genotype do not always show equal effects in other rice genotypes. This highlights the genetic area of epistasis, which has not been much explored. However, our improved understanding of these genes, and in many cases an improved understanding of physiological processes/ traits based on such genes, now allows us to use that knowledge and information in combination with high-throughput phenotyping, through normal conventional breeding. For example, the need to accelerate breeding can now be addressed through reduction of the generation time by manipulating the photoperiod – the time that a plant is exposed to light within a 24-hour period – with specific light regimes. Such an understanding of the physiological response at the systems level would not have been possible without biotechnology/molecular biology. Similarly, genes for increasing zinc in the rice grain have been identified through the use of molecular and phenotyping techniques, and the genomic regions/ genes will be used to mainstream grain zinc in all rice varieties coming out of the International Rice Research Institute (IRRI).

The world's main food crops



The 13 crops mentioned in blue rectangles are common for globally highest tonnage production and monetary value. With the 13, onions and peanuts make up the top 15 for tonnage production and coffee and cotton make up the top 15 for value. Rice has the highest global value of 337 billion dollars among all crops, while it is third in tonnage.

GENOMIC SELECTION AS A BREEDING TOOL

When marker-assisted selection (MAS) is performed at a very high density, genomic selection (GS) can be carried out. It mainly assesses the presence of a multitude of useful markers and predicts the extent to which a single or multiple traits can be favourably affected by the combination of the markers/ genes in a genotype. The technology is computer intensive, requires a set population and makes genome-wide assessment for predicting phenotypes resulting from biparental or multiparental populations. At IRRI, the plans for low-coverage sequencing of the entire genebank collections of rice accessions will feed the GS models in a very favourable manner for the models to be far more accurate, especially when combined with mechanical and automated phenotyping systems that process experiments and data at a high speed and accuracy (high-throughput phenotyping platforms).

CRISPR/CAS AS THE LATEST TOOL

Instead of random mutations all over the genomes, targeted mutation by Crispr will be of wide value in crop improvement. It can create the targeted mutations in a convenient and quick manner. For example, in hexaploid wheat, three homoalleles could be targeted by a single guide RNA to make the plants resistant to powdery mildew. Similarly for other complex traits controlled by multiple genes, regulatory genes such as transcription factor families could be targeted. Crispr has already been used to modify genes and traits in crops such as tobacco, rice, wheat, maize, tomatoes, cucumber, soybean, potatoes and cassava. Traits such as the fruit/grain quality/quantity, nutrient content (iron, phytic acid, carotenoid) and bacterial, viral and fungal disease resistance, drought and salinity tolerance, yield under drought, potassium deficiency tolerance and herbicide tolerance have been engineered. The ever increasing novel materials and methods for genome editing are bound to be one of the most useful technologies for modifying agronomic traits and thus improving plant breeding. In some countries, the products from this technology have not been placed under the purview of regulatory bodies. With Crispr, it is now easy to expect another green revolution.

FUTURE PROSPECTS WITH CROPS AND BIG DATA

There are 13 common crops in the top 15 crops by global tonnage and global value (see Figure). Along with the 13 common ones, onions and peanuts make up the two for top 15 in tonnage and coffee and cotton make up the two for top 15 in monetary value. There are international agricultural research centres (IARCs) devoted to improving the overall cultivation for seven of these crops (rice, wheat, maize, vegetables, potato, cassava, peanuts), mostly operating under the umbrella of the Consultative Group on International Agricultural Research (CGIAR) system. For the remaining ones, there are other IARCs and national centres. With genomic selection, Crispr and high-throughput phenotyping feeding into the respective big data construct, and set to play a widely critical role in crop improvement, there may be need to have standardised practices and and protocols that can be applicable to most if not all crops. Thus it is opportune to think of an international platform for archiving and disseminating the basic essential knowledge in these areas, along with providing a central hub for advocacy, after due diligence, for acceptance of Crispr-generated plants as the most evolved, precise, harmless, useful and benign technology in the service of humankind under an increasingly malignant climate change scenario.

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NERICA – TAILOR-MADE INNOVATION FOR AFRICA'S RAINFED RICE ECOLOGY

The organisation AfricaRice has committed itself to supporting African countries in their efforts to achieve self-sufficiency in the rice sector. In 1992, the organisation started working on interspecific hybridisation to develop varieties that combine the high yield potential of Asian rice with the local adaptation of African rice. In order to optimally consider the needs of smallholder farmers, a participatory approach was chosen for varietal selection. The farmers are also trained in seed production.

By Savitri Mohapatra

Africa is the only continent where the world's two species of cultivated rice are grown: Asian rice *(Oryza sativa)* and African rice *(O. glaberrima)*. While Asian rice is cultivated universally, African rice is unique to Africa. An international study published in 2018 led by the French Research Institute for Development (IRD), and co-authored by the Africa Rice Centre (AfricaRice) among others, revealed that the African rice was domesticated over 3,000 years ago in the Inner Niger Delta in northern Mali. Asian rice was introduced in East Africa over 1,000 years ago, and about 450 years ago, it reached West Africa. It quickly became popular because of its high yield potential and has largely displaced African rice in the region, which is relatively low-yielding, because it is prone to lodging and shattering. According to a study by Olga F. Linares, published in 2002, isolated pockets of *O. glaberrima* cultivation remain in Guinea Bissau, Guinea, Sierra Leone, and in the Casamance region of southern Senegal.

A GENETIC GOLDMINE

African rice is still grown in these areas for ceremonial and cultural values and appreciated for its taste and nutritional qualities. Some farmers in difficult environments continue to grow it in preference to the higher-yielding Asian rice because it is much better adapted to various local stresses. The hardiness of African rice results from its strong ability to compete with weeds and to withstand rice pests and diseases, drought, flood, infertile soils, iron toxicity and severe climates. This ability makes it an especially useful genetic resource for developing stress-tolerant rice varieties for rainfed ecosystems in Africa.

In contrast to Asia, most rice in sub-Saharan Africa (SSA) is grown under rainfed conditions, where production is risky. About 33 per cent of land under rice cultivation in SSA

The Upland Nerica-1 variety is popular in Cote d'Ivoire and Nigeria.

Photo: AfricaRice/ Rama Raman

Nerica L-19 is the most widely adopted lowland Nerica in sub-Saharan Africa.

Photo: AfricaRice/ Rama Raman

The AfricaRice genebank holds the largest collection of African rice in the world.

Photo: AfricaRice/ Rama Raman

represents the rainfed upland ecology, and 40 per cent belongs to the rainfed lowland ecology. Many of the poorest rice farmers depend on the upland ecosystem, where rice is grown without standing water and yield is very low.

In its work, AfricaRice, which has a pan-African mandate to develop the rice sector, has focused more on the resource-poor rainfed rice farmers, who had not benefited from previous research work to the same degree as those in more favourable rice-growing ecologies. It is also supporting efforts of African countries to achieve self-sufficiency in the rice sector. In 1992, the organisation decided to work on interspecific hybridisation to develop varieties that combine the high yield potential of Asian rice with the local adaptation of African rice. AfricaRice's collection of about 2,500 different kinds of African rice has served as a goldmine for this work.

COMBINING THE BEST OF BOTH WORLDS

Several attempts to access the African rice genome through interspecific crossing had been made by rice scientists in the past. However, most failed as crossing different species is complicated because of incompatibility barriers, so the probability of sterility in the offspring is high. AfricaRice circumvented the sterility barrier between the two species by using anther culture and embryo rescue techniques, coupled with back-crossings to the Asian rice parent. Several hundred interspecific progenies with promising agronomic performance were generated, increasing the biodiversity of rice.

The interspecific lines were evaluated across Africa by farmers through participatory varietal selection (PVS), which is an innovative approach that allows farmers to select their preferred varieties that match their needs and growing conditions. PVS also generates valuable feedback on farmers' preference criteria for rice breeders (see upper Box on page 15).

The most successful lines, based on their performance and popularity among farmers, were named the New Rice for Africa (Nerica) varieties. Nerica is now a household name in Africa – synonymous with the work that earned AfricaRice several international awards including the World Food Prize conferred in 2004 to plant biologist Monty Jones, who was Sierra Leone's Minister of Agriculture from February 2016 to March 2018.

HIGH-YIELDING, EARLY-MATURING, STRESS-TOLERANT, RICH IN PROTEIN

The first Nerica varieties were released in Côte d'Ivoire in 2000. Upland Nerica varieties give yields that are generally as good as the Asian rice varieties. They are early-maturing (75-100 days) and are relatively tolerant to major stresses of Africa's harsh growth environment. However, not all these characteristics are found in one single Nerica variety. Early maturity for example is much appreciated by farmers, especially women farmers, as it allows them to have food during the 'hunger period' while waiting for the harvest of other crops. Additionally, studies show that some Nerica varieties have on average a 25 per cent higher protein content than imported Asian varieties. Currently, there are 18 Nerica varieties (Nerica-1 to Nerica-18) suited for upland growth conditions. Nerica-4, which is tolerant to drought and phosphorus deficiency, is the most widely adopted upland variety, grown in more than ten SSA countries.

In 1998/1999, AfricaRice started to extend its Nerica programme to the rainfed lowland ecosystem. The lowlands – where rice is grown in bunded fields that are flooded for at least part of the growing season – are generally more fertile than the uplands. In West Africa, the lowlands represent about 20–50 million hectares, so they offer great potential for the sustainable expansion and intensification of rice. The development of the lowland varieties was facilitated through the shuttle-breeding approach (see Insert below) in partnership with national programmes in West and Central Africa through a task force mechanism to accelerate the selection process and achieve wide adaptability of the lowland Nericas.

Sixty rainfed lowland Nerica varieties (Nerica-L) were selected by farmers in several African countries through the PVS process, including over 550 farmers in Burkina Faso. The varieties have a yield potential of six to seven tonnes per hectare and a good resistance to major lowland stresses such as iron toxicity and weed infestation or highly destructive diseases (e.g. the rice yellow mottle virus – RYMV) and pests (e.g. the African rice gall midge – AfRGM, stemborers or nematodes). The first lowland Nericas were released in 2005. Nerica-L-19 is the most widely adopted lowland Nerica in SSA.

Shuttle breeding uses diverse ecological environments to develop improved varieties with higher adaptability. Alternate generations of early breeding materials are grown under different environments.

In total there are now 82 Nerica varieties – 18 upland, 60 lowland and four irrigated. The success of these varieties has now expanded beyond the African continent, with Nericas being used by farmers and breeders for rice production and varietal improvement programmes in Bangladesh, China, India and several other countries around the world.

A BROAD-BASED PARTNERSHIP

A project like the Nerica breeding programme cannot be implemented by one organisation alone. Various research and development partnerships were forged to support the development and dissemination of Nericas (see lower Box on page 15). A major landmark was the launching of the African Development Bank (AfDB)-funded Multinational Nerica Rice Dissemination Project (2005-2010). The project sought to widely establish Nerica and other

improved varieties in seven countries: Benin, The Gambia, Ghana, Guinea, Mali, Nigeria and Sierra Leone. Through these programmes, policy-makers were encouraged to support the effective dissemination of Nericas and other improved rice varieties as well as complementary technologies across Africa.

Many studies have shown the wide adaptation of Nerica varieties and their impact on farmers' livelihoods in SSA. An impact study in 2018 demonstrates that the adoption of Nerica varieties had brought food security to 7.2 million people and lifted about eight million people out of poverty in 16 African countries. Today, Nericas cover over 1.4 million hectares in SSA.

Despite this progress, the project has been confronted with a number of bottlenecks, the most important with regard to Nerica diffusion being the lack of seed. In many SSA countries, national seed regulatory bodies do not function efficiently. Therefore, AfricaRice adopted the community-based seed system (CBSS) approach, whereby farmers are trained to produce 'seed of acceptable quality' (see Box on the right). The other constraints are the desperate lack of capacity at all levels in the rice value chain, lack of access to fertiliser and credit as well as inadequate rice production, processing, distribution and marketing infrastructure.

WHAT'S NEXT?

AfricaRice's breakthrough in developing the Nericas offers a great opportunity for sustainable agricultural development in the rainfed environments, where most of Africa's rice farmers earn a living. They are, however, just part of the portfolio of AfricaRice to help SSA achieve rice self-sufficiency. The Center and its partners are developing the next generation of rice varieties that can respond to consumer demand and adapt to both current and future climate scenarios.

The Center is increasingly focusing on an integrated seed-to-plate value chain approach to achieve a sustainable linkage between rice production, processing and marketing. Upgrading the rice value chain will reduce reliance on imports, increase food security, increase gender equity, reduce urban migration and give Africa's youth valuable employment opportunities.

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INVOLVING FARMERS IN THE BREEDING PROCESS

A **participatory varietal selection (PVS)** approach was adopted to enable farmers and plant breeders to collectively identify improved varieties, including Nerica varieties, best suited to the producers. The PVS process takes three years. In the first year, 'rice gardens' are established in villages by research and extension, associated with leading and innovative farmers or farmers' organisation. These gardens have a large selection of rice. Around 60 lines are presented to farmers in the form of a village-based demonstration plot.

At the end of the first year, the researchers ask the farmers to name up to five varieties that attract them most, and to state the reasons for their choices. Trials on cooking characteristics and taste are also carried out at this stage. During the second year, the farmers are given seed of the varieties they have named and are invited to try it out for themselves, comparing it with their traditional varieties. In the third year, the farmers are asked to pay for the seed if they wish to continue using it.

Within an agro-ecological zone, the most popular four or five lines selected are then multiplied and diffused to up to 500 farmers for evaluation over two seasons. The lines most appreciated by the farmers are recommended for zonal release. In the PVS process, special attention is paid to getting feedback from women farmers, whose preferences often turned out to be quite different from those of men. PVS revealed that men gave importance to plant height, whereas women preferred traits such as good emergence and seedling vigour.
PVS worked well for the Nerica programme, giving farmers the varieties they wanted, and generating valuable feedback for the breeders. PVS trials were linked to varietal release mechanisms where possible and seed production projects to speed up adoption. A participatory approach involving farmers is still being used by AfricaRice throughout Africa.

In the absence of a formal seed sector in many sub-Saharan countries, farmers remain dominant as seed sources. AfricaRice adopted the **community-based seed system (CBSS)** approach to stimulate farmers in taking the lead in ensuring adequate supplies of quality seed for rapid dissemination of the improved varieties once they were officially approved for release.

CBSS is designed to enable smallholders to meet their seed requirements by improving their knowhow in basic seed production and quality constraints. Seed production and distribution are done according to the farmers' practices and capabilities, with some simple guidance given to help farmers maintain the purity of seeds for a period of three to five years. CBSS was instrumental in the production of seed used in the PVS trials. It became a powerful mechanism in integrating traditional knowledge systems into modern technologies, partnering with farmers and national extension services to respond to a major gap in the seed sector.

RESEARCH PARTNERS AND DONORS

The Interspecific Hybridization Project launched in 1996 brought together the national rice research programmes in SSA, the International Rice Research Institute (IRRI), China's Yunnan Academy of Agricultural Sciences (YAAS), the University of Tokyo, the Japan International Research Center for Agricultural Sciences (JIRCAS), the International Center for Tropical Agriculture (CIAT), the French Institute of Research and Development (IRD), Cornell University and the UK-based Natural Resources Institute (NRI).

The African Rice Initiative was launched in 2001 to promote the widespread and rapid diffusion of the Nericas. AfricaRice's work on interspecific hybridisation and Nerica development, testing and dissemination has been generously supported by the African Development Bank (AfDB), the Consultative Group on International Agricultural Research (CGIAR), the European Union, Belgium, Canada, France, Germany, Japan, the Netherlands, Norway, Sweden, the UK, the USA, the Food and Agriculture Organization of the United Nations (FAO), the Gatsby Foundation, the Rockefeller Foundation, the International Fund for Agricultural Development (IFAD), Sasakawa-Global 2000, the United Nations Development Programme (UNDP), the United Nations Office for South-South Cooperation (UNOSSC), the World Bank, the World Food Programme and World Vision International.

THE EU RULING ON PLANT BREEDING AND WHAT IT MEANS FOR AFRICA

New plant breeding technologies (NPBTs) allow biotic and abiotic problems in crop production to be addressed much faster and more precisely than conventional ones. Legal regulations governing the use of technologies vary from country to country. Above all the latest ruling by the European Court of Justice has sparked debate. Our authors look at the implications that the decision taken by the European Union could have for African agriculture and call on African policy-makers not to reject certain strategies and technologies out of hand.

By Kai Purnhagen and Justus Wesseler

A debate has emerged about the proper regulation of New Plant Breeding Technologies (NPBTs) such as genome editing. A recent judgement of the Court of Justice of the European Union (CJEU) stipulated that, for the EU market, many of the NPBTs need to follow the provisions applicable to genetically modified organisms (GMOs). In its decision, the Court interpreted EU law in a conservative way, based on the scientific information provided to the Court during the proceedings. It interpreted the existing exemption for organisms obtained by mutagenesis restrictively, exempting only techniques that "have conventionally been used in a number of applications and have a long safety record". This interpretation pulled many NPBTs such as CRISPR/Cas within the ambit of the GMO law. The decision by the CJEU has been criticised by many, most notably the scientific community and the plant breeding sector. Contrary to what is sometimes assumed, the decision does not imply a total ban of such novel techniques in the EU market. Rather, it imposes, inter alia, an authorisation requirement. Yet, crops that fall under the GMO regulation face increasing costs because an approval procedure has to be followed. Consequently, there are many calls for adjusting the EU legislation to new developments in plant breeding.

Not binding, but setting an example. Many African countries adopt the EU view when it comes to plant breeding. This could also apply to the recent CJEU judgement on NPBTs.

Photo: Bilderbox.com

TRADE OBSTACLES

The judgement has implications not only for plant breeding and farmers in the EU, but also for imports of agricultural commodities and food products into the EU. Most imported agricultural commodities and food products derived from crops within the scope of EU GMO legislation need approval for import and processing and require labelling. This results in additional costs for those companies that export into the EU. But labelling will also be a challenge for another reason. Many of the applications of NPBTs cannot be distinguished from natural mutation in the final product. The products derived from NPBTs have the characteristic of what economists call a "credence" good, which means that the characteristic of the product cannot be identified by simple visual inspection, just like with food produced under organic labels. As a consequence, tracking and tracing systems similar to what we observe in the market for organic food products could be implemented. And this could further increase the costs and results in problems known from tracking and tracing of organic food products.

These implications do not necessarily directly result in negative effects for Africa. African countries do not need to follow the decision of the CJEU or the EU regulatory framework for GMOs for their own markets. If their national legal system allows them to, African countries can use NPBTs for improving the crops they cultivate. Issues may arise related to trading crops and derived products with EU markets. The more important effect will be indirect. Many African countries follow the view of the EU when it comes to plant breeding, and they might be reluctant to approve the use of NPBTs. Within Africa, the legal status of NPBTs may differ by country and cause trade disruptions within Africa as well as in relationships with the EU and countries in other regions.

At this point in time, as the use of the NPBTs for African crops is still under development, it is difficult to predict how countries will respond, but previous experiences with transgenic crops provide some insights. So far, according to the International Service for the Acquisition of Agri-biotech Applications (ISAAA), only transgenic cotton (Burkina Faso, Ethiopia, Nigeria, South Africa, Sudan, Swaziland), maize (Egypt, South Africa), soybean (South Africa) and cow pea (Nigeria) have received approval for cultivation in Africa. Kenya, e.g., has not approved the cultivation of Bt maize – maize that bears the Bt protein, which makes it resistant to infestation with nematodes such as the corn borer – for more than twenty years, the process having got stuck in bureaucracy, and Uganda has still not given its approval to the cultivation of transgenic banana after ten years. Both are important staple crops in the respective countries.

A THREAT TO RESEARCH ON AFRICAN CROPS?

Another indirect effect is that investments in NPBTs by the private sector might be lower than otherwise and applications by international plant breeding companies could be reduced

for crops of importance for African agriculture. Domestic plant breeding companies may be an alternative. The difficulty is that many of the technologies and the germ plasm being used for plant breeding are often not in the hands of one single company. Technologies and germ plasm are shared between plant breeding companies using cross licensing of technologies and other forms of partnerships often as a result of protection of intellectual properties via patents and plant breeders rights. International smaller and larger plant breeding companies hold shares on African companies and vice versa. The private seed sector is in particular well developed in South Africa, ranked number 16 world-wide in terms of value.

The larger problem is the potential lack of interest caused by regulatory uncertainty in African countries and the EU. The EU judgement increases legal uncertainty as the direct implications and possible changes in EU regulation are under debate. African countries send a number of mixed signals about their intentions to introduce reliable approval systems, and all the more about final approval, as illustrated by the long debates about the approval of Bt maize in Kenya and disease resistant banana in Uganda. Both lower economic interest among plant breeders and the approval systems and related uncertainties reduce the returns to investment in plant breeding from a social welfare point of view. Recently, the Nagoya Protocol (see Box) has increased the regulatory uncertainty further as many aspects related to access and benefit sharing are not solved. Out of the 54 African signatory countries to the protocol, at this point in time, only 17 have identified national competent authorities for handling Nagoya protocol-related issues and only two, Kenya and Cameroon, have identified procedures to follow according to the Access and Benefit-sharing Clearing House (ABSCH). The cases of transgenic maize for Kenya and transgenic banana for Uganda serve as examples from the application of transgenic methods.

The above-mentioned indirect implications for Africa are expected to be substantial. Challenges posed by climate change such as changes in pest and disease problems or abiotic stress (e.g. droughts, soil salinity) require responses where NPBTs can help as they are cheaper, more precise and much faster in providing improved plants than conventional breeding techniques. Examples include maize and cow peas resistant to corn borers and other pests. One illustrative example is the outbreak of the fall armyworm in sub-Saharan Africa (SSA) two years ago. The fall armyworm is a sub-species introduced from South America and not endemic to SSA. Farmers were facing losses of up to 100 per cent in maize production. Recommended solutions included the heavy use of insecticides. Pest resistant Bt maize provides protection against the fall armyworm, but African countries are reluctant to approve the technology. While the Bt maize is a transgenic variety, similar resistance could also be developed by using NPBTs.

The Nagoya Protocol – or, as it is known in full, the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization to the Convention on Biological Diversity – was adopted in the city of Nagoya, Japan. It is a supplementary agreement to the 1992 Convention on Biological Diversity (CBD) and aims at sharing the benefits from the utilisation of genetic resources in a fair and equitable way. Ratified by 114 parties, which include 113 UN member states and the European Union, it entered into force on the 12th October 2014.

MANY ADVANTAGES FOR SMALL-SCALE FARMERS

The experiences of Bt maize cultivation within South Africa illustrate that not only larger farmers have an interest in the technology but smaller farmers do as well. In particular, smaller and poorer farmers are expected to benefit more from the technology than larger and/or wealthier farmers. The technology is embodied in the seeds and provides access independent of farm size. Further, pest resistant seeds result in larger yield increases among farmers without the resources to purchase pesticides or other pest-control products. A third advantage is the low level of knowledge intensity required. Experiences from cotton in Asia show a rapid adoption of the technology once it becomes available. Another advantage is its contribution to the empowerment of female household labour. The use of total herbicides (none-selective herbicides) has substantially increased among smallholder farmers, reducing burdensome hand-weeding. The benefits of using total herbicides can be further increased by introducing herbicide resistant crops. However, it has to be borne in mind that potential problems related to herbicide resistance may emerge and deserve attention.

Pest and herbicide resistant crops are just two examples of technologies that are more or less available and can be adopted to local crops using NPBTs. What is important to consider is that the combination of damage-reducing technologies needs to go hand in hand with nutrient improvements. Higher yields demand higher amounts of nutrients – an aspect that needs to be considered when implementing the technology, especially with regard to smallholder conditions.

NPBTs are not only reckoned to provide strategies for addressing biotic and abiotic problems in plant production. They can also be used as a tool for biofortification with the expectation of substantial health benefits such as Vitamin A-enriched rice.

ABOVE ALL AN INSTITUTIONAL AND POLITICAL PROBLEM

NPBTs are only one among many possible solutions to address problems in plant production and micro-nutrient deficiency. A number of other strategies exist as well, such as improved cultivation practices including fertiliser use. From an ex-ante perspective, it is difficult to identify what will be the best solution for farmer A in region B. The individual circumstances differ widely. What the experiences until now tell us is that addressing crop production problems is less of a technical problem. Many possible solutions exist. In Africa, addressing crop production problems is an institutional and political problem. And as long as these kinds of problems are not solved, having technical solutions is fine, but they will hardly reach farmers, or if they do, only those preferred by policy-makers and others involved in the decision-making processes.

Excluding one possible strategy and NPBTs in particular reduces the potential for effectively addressing important problems. African policy-makers should not discriminate against one or the other strategy and keep options alive to save lives.

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For references and further reading, see online version of this article at: **www.rural21.com**

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DIVORCED FROM REALITY

In one of the most important policy fields in development cooperation, rural development, German NGOs are not maintaining a convincing discourse, our author claims. Why the African continent isn't benefiting from Western criticism of prosperity.

By Ingo Melchers

Combating poverty and supporting agricultural development deserve a high status in German development cooperation. In addition to the construction industry, it is above all agriculture that holds the potential to get millions of young, unskilled people into productive employment as quickly as possible. The case of Algeria shows that this does not go without saying. There, eleven generals – known as "Barons" – control the imports of everything that the Algerians need. Local production of food would undermine the Barons' business model. To them, "politics" means defending their monopolies and privileges. In contrast, forward-looking and politically responsible politics in Africa means strengthening the political and economic actors committed to the goal of economic development with a broad impact – businesses that invest, civil society organisations which stand up against despotism and for the rule of law, politicians and parties that seek to create an environment conducive to employment. Sustainable impacts are achieved – provided that the local producers raise their productivity.

THE PRIVATE SECTOR – AN IMPORTANT PARTNER

However, it is not the governments on their own – let alone development cooperation – that are capable of mastering this task of the century. Hundreds of thousands of small, medium and large enterprises are called on here to grasp new opportunities, try out business models holding good prospects, introduce innovations – in a nutshell, to take risks and create jobs. The obvious consequence for development cooperation is to seek collaboration with businesses in Africa, but also from Europe, that are eager to invest in Africa and develop its future. Correspondingly, it is the practice of rural development performed by the German Federal Ministry for Economic Cooperation and Development (BMZ) to support innovative approaches and actors with broad participation. The result is that the promotion of agricultural value chains can show impressive figures. Together with strong partners from governments, businesses, science and civil society, alone in the supply chains of cotton, cashew, rice and cocoa, development cooperation has succeeded in creating 850,000 jobs (fulltime equivalents).

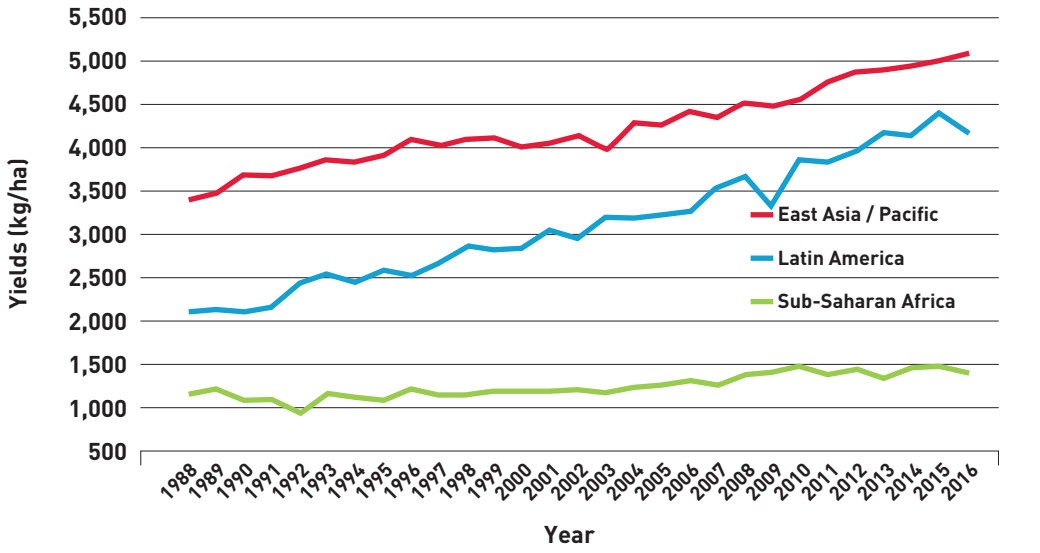
Development cooperation practice by no means seeks to transfer money to businesses, as some may suspect, but to develop and implement those projects together with them that are worthy of support from a development angle. Such an approach reaches out to and builds capacities among far more farms, suppliers, providers of services or manufacturers than would be possible by relying solely on development cooperation. Thus the latter's impact is multiplied. Without any doubt, the private sector is of crucial importance to Africa's rural economy making progress of its own accord, to substituting imports and to creating good employment. Why is collaboration between development cooperation and the private sector so strongly rejected by influential NGOs and church relief organisations in Germany?

An "Argumentarium" presented by Misereor provides initial clues. Here, many illustrations and items worthy of note are provided regarding the significance of diversity in dietary habits. However, the prime objective is a critique of corporations and in particular so-called "industrial agriculture". Given the partly negative impacts of European agricultural policy, with very intensive farming in Germany, such criticism falls on open ears in relevant circles among the German public. High levels of groundwater pollution with nitrates e.g. in the northwest of Lower Saxony are rightly criticised. But are these and other points of criticism of a Western European affluent society suited as a pattern to analyse or provide a context of justification for German development cooperation seeking to improve economic and social prospects in rural areas of Africa?

"INDUSTRIAL AGRICULTURE" VERSUS "AGROECOLOGY"?

The term "agroecology" has met with a wide range of different interpretations, perceptions and moral values. The concept is not clearly de-

Cereal yields in selected world regions



Source: the author's own compilation based on World Bank data.

fined or verifiable with straightforward criteria, as is e.g. required for certification in "organic farming". Whereas many somehow understand "agroecology" as a synonym for "holistic", "locationally suitable farming" or "sustainable agriculture", to German NGOs and church relief organisations, the concept tends to describe the ideal notion of local and solidary "agrarian culture" which, however, ignores interests, costs or prices – and above all contrasts sharply with what is criticised most of all: "industrial agriculture".

This does not represent any instructions for a political analysis, and it is not recognisable what the role of agriculture can play in medium-term economic development. In particular, the use of externally procured inputs such as seed, fertiliser or machines is criticised. Neither should farmers make themselves dependent on banks, it is argued. Whereas German farmers very easily find access to seed, fertiliser and financial services (depositing money, savings, loans) in local agricultural trade and service facilities, this only applies to a very limited degree for their African colleagues. Experience from many rural development projects in Africa shows that those enjoying access to fertiliser will, as a rule, use it. Not only does certified seed enable higher yields, it also guarantees high germination rates and healthy growth, while such properties are more rarely available in bartered or farm-saved seed. This is probably also the reason why most European farmers buy seed rather than bartering it locally. Does this make the European farmers more dependent than those in Burkina Faso?

One aspect that is usually missing in this discussion relates to soil fertility. Agricultural land in Africa often has low levels of nutrients. If it is not fertilised – in whatever manner – it becomes subject to leaching. Usually, sufficient amounts of organic fertiliser are not available, also because crop farming and animal husbandry are often not practised on the same farm and are frequently even performed by different ethnic groups. Without fertiliser use permanent farming means "soil mining", overexploiting the soil – with the lack of fertiliser leading to an albeit destructive practice. It is quite wrong to idealise such practice.

The World Bank states that fertiliser consumption in sub-Saharan Africa rose between 2003 and 2016 – by more than 50 per cent in some countries. However, this development had started out from such a low level that by 2016, an average of a mere 16.2 kg of fertiliser was being spread per hectare (compared to Germany's 200 kg/ha). In countries with relative political stability and economic dynamics, the values were partly higher (38 kg in Kenya, 22 kg in Ghana). Is this what should be condemned as "industrial agriculture"?

In simple terms, no African area state is attaining the fertiliser intensity levels that are widespread in Europe. The situation is similar regarding the use of enhanced seed. Moreover, anyone familiar with African agriculture will accept that innovative practices are needed to develop smallholder-appropriate mechanisation. For just like their peers elsewhere, young Africans are geared more to the smartphone than to the hoe. Jobs that only promise hard physical labour and poor and uncertain pay are not attractive anywhere in the world. People do not choose them in Africa as an option, either, but at best endure them for lack of options. Raising the productivity of

African agriculture is the way to increase rural income. Otherwise, young people in particular will vote with their feet.

WHAT ABOUT PRODUCTIVITY?

And as a result, what is the state of productivity in Africa's agriculture? Quite obviously, there are considerable differences. In some countries and project regions, agriculture has seen positive developments over the last few years. However, summing up the situation across the entire regions south of the Sahara, results have been sobering. Whereas yields have risen continuously throughout all other world regions, sub-Saharan Africa as a whole has seen development stay significantly below the average (see Diagram on page 19).

We can read on the Bread for the World website: "What is crucial is not that agricultural production is increased at all accounts, but that food and the means of production to produce it are available where they are really needed." Whatever this is meant to imply, the reason for poor agricultural production is always poor policies to the detriment of the poor in particular. The consequences are high costs for the people, the environment and society: soil-leaching, low income for African farmers and high food prices for African consumers. It is problematic for NGOs to virtually play down the situation that African agriculture is in and do so as if there is no need for modernisation or structural change.

Disdain for increases in productivity also appears to be questionable given the current global developments of stocks, production and consumption of cereals. In April 2019, the United Nations Food and Agriculture Organization (FAO) published its latest and rather worrying estimate. For the first time in many years, annual production figures are falling below the level of consumption – against the background of declining stocks. While this is not immediately presenting problems because the warehouses are still relatively full, it is obvious that further growth of the world population is going to keep the pressure on quantities and prices.

Scepticism towards externally procured inputs has to be viewed critically from a very different angle, as well. For agriculture can only turn into a job machine through the integration of various sectors. The demand among farms for semi-manufactured products, machines and services creates additional good jobs in the rural regions. And by supplying sufficient quantities of high-value agricultural produce, jobs in the trade, processing, transport and quality-control sectors are created and innovations are encouraged. Via such mutual coupling of sectors and business linkages, an integrated and dynamically growing agricultural and food sector develops. Agriculture not integrated in this cycle stays poor. It does not create any productive employment – neither in the field nor in the upstream and downstream sectors.

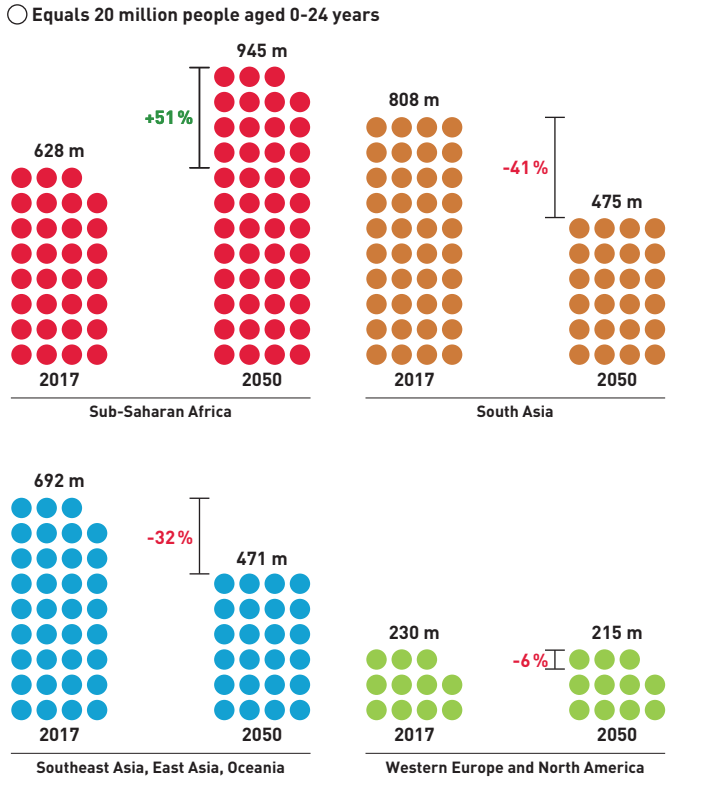
WESTERN LIFESTYLES ARE NOT COMBATING HUNGER IN AFRICA

Of course calling for a different agricultural policy and more sustainable dietary habits in Germany and Europe is legitimate and as such more than comprehensible. But the German agricultural and food sector is suffering from problems very different from those in Africa. Seeking to prescribe the same recipes for both situations is bound to meet with failure. Only the African farmers themselves can decide how land should be used and which crops need to be grown. Whether rice, maize or sorghum is consumed can only be decided by the African consumers. And finally, it is not up to development cooperation but lies with the responsibility of democratically legitimised governments to decide which promotional tools are to be applied and with which actors cooperation is to be sought. Some NGO publications focusing not so much on concrete practice in projects but on the discourse over agriculture and on cooperation with the business sector are very biased and formulated in an all too absolutistic language. Sometimes, they lack respect for an autonomous opinion and decision-making in Africa.

NO POLITICAL ANALYSIS

Perhaps the most critical item regarding the large number of discourse papers produced by NGOs and church relief organisations is the lack of a country-specific political analysis of the political actors, the real options for action, the strategies or inconsistencies. Which actors, which concrete political alliances can government or non-governmental development cooperation directly or indirectly support in order to promote a broad-based, socially inclusive and responsible rural transformation rather than restricting efforts to niches? No issue. The empirically well-documented link between investment, economic growth and productive employment to combat hunger and poverty is widely ignored. Nigeria, for example, has been debating the "right" economic policy approach for years. The issue in this country is hardly that of good or bad, but of the complex management of competing risks. There are modernisation-friendly actors among the investors, farmers, agricultural merchants, NGOs, service providers and politicians. They are opting for a dynamically growing agriculture and food sector with its enormous employment effects. They are faced with a politically well-integrated phalanx of food importers and the representatives of the old oil industry who have set their sights on importing food to supply the urban population – and to secure their privileges. And it is precisely here that church relief organisations and NGOs are campaigning again and again, and quite generally, against development cooperation working together with partners in the business sector, which really can be referred to as an "unholy alliance". This effectively puts some NGOs and church relief or-

Youth population trends up to 2050



Source: Brookings

ganisations in the field of rural development on the wrong side politically – on the side of an old elite that displays no interest in eradicating poverty. It is this old elite that supplies feed for the religious fanatics. In Africa, new transformative leadership ranks are currently being formed that deserve broad alliances – also in Germany.

Venro is the legitimate federation of development cooperation and humanitarian relief in Germany. The Venro website says only little about agricultural development in Africa. The federation refrains from presenting any position of its own on a central development issue. Thus Venro leaves the maintaining of a discourse to a small NGO working group that presents some of its tendentious publications all too confidently as "the German NGO view". This does not reflect the views of African rural youth, African agricultural policy or African civil society.

THE FUTURE OF AGRICULTURE LIES WITH THE SMALL-SCALE FARMING!

According to the Center for Development Cooperation (ZEF), based in Bonn/Germany, there are a current approximately 570 million smallholdings world-wide. There is a tendency for the average size of farms to rise in economically more developed countries and to fall in poor countries, especially in sub-Saharan Africa, which appears to indicate that employment alternatives outside the agricultural sector are hard to come by. But even with the unrealistic assumption of an extremely high emigration rate of five per cent a year, ZEF maintains that it would take 45 years to evolve from an average farm size of one hectare to ten hectares. An emigration rate of one to two per cent a year seems to be far more realistic for Africa.

So, everything suggests that in 50 years' time, the vast majority of Africa's farms will still be smallholdings. Hence the African governments' agricultural, economic and social policies as well as businesses in the upstream and downstream sectors are well advised to arrange for this and orient their practice on treating smallholder farms and their producer cooperatives as business partners. Highly mechanised farming covering large areas will continue to be an exception, both in Asia and in Africa. Family farms with their flexible labour force are more resilient in times of crisis, and in normal periods, they are better positioned to adapt to changing conditions and grasp opportunities. Compared to large-area farming, the family farm, provided that it can rely on both traditional and new technologies, will remain competitive. Karl Kautsky already predicted the death of the smallholder in 1899. He was wrong about this. Smallholders are there to stay over coming generations.

DEVELOPMENT COOPERATION AND SECURITY POLICY

Openly contradicting the US administration, Germany's Federal Chancellor Angela Merkel argued at the Munich Security Conference on the 16th February 2019 that for Germany, both the military and development cooperation belong to a holistic understanding of security policy. In Germany, this is anything but an exaggerated party-political position. On the contrary, a very broad majority of the population are probably of the same opinion.

According to Brookings/Mariama Sow, sub-Saharan Africa is the only region in which the youth population is set to rise further up to 2050 – both in absolute terms and in percentages (see Diagram). One key task and responsibility of African leadership over the next 20 years is to develop structural transformation politically in a form that enables the potentially explosive forces resulting from the rural exodus, unemployment and ethnic or religious tension to be steered into civil and productive channels. Raising income levels for millions of unskilled young people could be the most important element in this context. All in all, there is a powerful rationale in terms of humanitarian, economic, civilisational as well as security policy justification for more productive agriculture. Promoting agriculture and the food industry may not be the only prerequisite in this context, but it is certainly an important one and ought to be part of a medium-term strategic wager. Here, development cooperation must not be overestimated: the real debates on economic and social policies are taking place in the countries themselves. Nevertheless, there is no reason to omit agricultural development in particular from such an overarching logic of development cooperation, for it can indeed contribute to economic and social modernisation and is in fact already doing so. Thus, it ought to be appreciated that this requires a strategic and practical move towards working together with business in order to remain relevant in this policy field and achieve tangible impacts.

MAJOR INFLUENCE = A MAJOR RESPONSIBILITY

Summing up, it has to be said that, unlike many NGOs in other European countries, regarding combating hunger/agriculture, German civil society has reached a dead end both analytically and politically. In substance, its positions represent an unintentional, albeit disturbing alliance with privileges and monopolies, with an authoritarian past and structural poverty that rural African youth want to leave behind once and for all.

In the thematic field of rural development, church relief organisations and NGOs have a considerable influence on politics and the formation of public opinion. This ought to be reflected by greater realism and, above all, political responsibility for what they write and demand. It is the rural economy of poverty, devoid of technology as well as prospects, that is driving millions of young people into the cities. The characteristic style of many NGOs that displays hostility towards business and technology may somehow seem to be left-wing and critical. But it really boils down to ahistorical and apolitical structural conservatism that is at odds with the burgeoning middle classes and youth striving for modest affluence and employment. More efforts ought to be made in analysing the contradictory political actors and power relationships in Africa's individual countries. Just like in every other democracy, the object is not that of asserting idealistic concepts of minorities but organising and negotiating majorities. It is there, and not in Germany, that the conflicts are resolved that set the course for the future.

And while the accent is on more sustainability and quality in Germany, Africa is facing dramatic changes: rapid urbanisation, rural transformation, technological progress and the increasingly important role of business in rural areas. Given Africa's demographic development, according to the African Development Bank, food imports are to rise to 110 billion dollars a year by 2025 – unless African agriculture can respond more dynamically to growing demand. Otherwise, millions and millions of jobs will not be created. What is really at stake is much more than merely a certain type of agriculture. Any poetry of the future for real rural Africa requires in the very first place responsible policies for prosperity and peace.

The positions put forward here are private opinions.

For references and further reading, see online version of this article at: **www.rural21.com**

EMBRACING CHANGE

HOW FAMILY FARMERS CAN FACE THE FUTURE

This year opens the Decade of Family Farming, which aims to improve the life of family farmers around the world. In an earnest discussion, two leaders in the global agriculture community reflect on the challenges facing family farmers, the promises of high- and low-tech solutions, and their hopes for the future. A conversation between Martin Kropff, Director General of the International Maize and Wheat Improvement Centre (CIMMYT), and Trevor Nicholls, CEO of the Centre for Agriculture and Biosciences International (CABI)...

Trevor Nicholls, CABI

...ON THE UNIQUE CHALLENGES FACING FAMILY FARMS

Trevor Nicholls: Family farmers come in many shapes and sizes, but for me, the word 'family farmer' bring a focus on smallholders and people who are starting on a journey of making a farming business. It depends on which part of the world you're talking about; a family farm in the UK is perhaps very different to a small family farm in Ethiopia. And family farms can grow from just a small plot to being quite large commercial enterprises.

Martin Kropff: All agriculture started with family farms. Fifty years ago in my home country, the Netherlands, almost all farms were family farms. When we look globally, farms in places like India, Pakistan, and Kenya are very often small, and the whole family is involved.

When the whole family is involved, gender dynamics come out. In a way, family farming is very often the farming done by women. This makes women the most important players in agriculture in many developing countries. It's crucial to recognise this and understand their decision-making. For example, our research shows that men and women value different traits in crop varieties. We need to understand this to have successful interventions.

Nicholls: We've seen something similar through our Plantwise plant clinics, where farmers come for practical plant health advice. We can observe a definite pattern of men bringing in cash crops for advice, and women looking more at fruits and vegetables to feed their family. But overall, mostly men come into our clinics, particularly in certain parts of the world. We're trying to encourage more female participation by timing the clinics so that they fit into women's routines without getting in the way of taking care of elderly relatives or getting kids off to school. Sometimes really simple things can open up access and improve the gender balance.

Kropff: When the whole family is involved, there are also downsides. In Africa, young people do much of the weeding.

Nicholls: That's right, they may be pulled out of school for weeding.

Kropff: This really worries me. Hand weeding is such hard labour, such an intensive use of energy; it seems like it should be something of the past. Children don't want to do it anymore. My wife is from the generation where children still did weeding in the Netherlands. She remembers standing in the fields weeding when the sun was extremely hot while her friends were out doing other things.

Nicholls: It starts kids off on the wrong path, doesn't it? If their experience of farming is backbreaking weeding from the age of eight onwards, it's highly unlikely to attract them into farming as a career.

...ON KEEPING YOUNG PEOPLE INTERESTED IN FARMING

Nicholls: We need to look at things like weed control as a social issue. It's possible, for example, to use beneficial insects to limit the spread of certain weeds that infest farmland. Biocontrol and Integrated Pest Management should be seen as ways of reducing the spread of certain weeds, and also as ways to reduce the burden on women and youth.

Kropff: I agree. Similarly, we're finding that small-scale mechanisation is making a difference for youth, and also women's labour in Latin America, Africa and Asia, where Cimmyt has been introducing two-wheel tractors that can be engineered in local workshops. Suddenly, smallholders can harvest the entire wheat crop of 20 families in one day. This saves so much time, money and effort, eliminating some of the 'bad' labour that may discourage youth and unfairly burden women. Farmers can focus on the 'nice' aspects of the business. It's a real game changer for family farming.

Nicholls: Yes, and this can also be amplified through digital technology. People refer to the "Uber-isation" of tractors, where farmers are able to hire a piece of mechanical equipment for a very short space of time, and maybe it even comes with an experienced driver or operator. We're finding that digital tools like artificial intelligence, satellite imaging, smartphones, and other modern technologies will intrigue youth anywhere in the world. These will hopefully have an impact on bringing more youth back into farming, as they start to see it as technologically enabled rather than straightforward muscle power.

...ON THE TRANSFORMATIONS THAT NEED TO HAPPEN

Kropff: If we want to keep youth engaged, and improve farmers' livelihoods, I think farming needs to become more entrepreneurial. Many family farms are only half a hectare. I think this has to grow somehow, though land rights and ownership are a challenge.

Nicholls: As farming becomes more business-like in Africa, we're going to see the same sort of consolidation that we saw in the United States and Europe, whereby

Martin Kropff, CIMMYT

farm sizes do get larger even if land ownership remains fragmented.

This could happen through cooperatives, which offer economies of scale and also help farmers spread the costs of things like access to inputs, advice, weather insurance and crop insurance. But we need to view cooperatives as more than a way to infuse new technologies into the farming system. They are in fact a channel for helping farmers gain stronger business skills, so they can get a better bargain for themselves.

Kropff: In Mexico, we are working with 300,000 smallholder farmers in a sustainable maize and wheat sourcing initiative. Rather than 'pushing' new varieties and technologies onto farmers, we help them partner with maize and wheat companies to create a local demand for high quality, sustainable products. Real scaling up, especially for wheat and maize, needs more than extension. Farmers need better links to the market.

Nicholls: If farms get larger and more mechanised, it means fewer people are involved in the business of farming. This shift means that people will need other rural occupations, so that they don't just leave the land and move to the city. We need investments in other productive activities in rural areas. This could be around post-harvest processing of crops – adding value locally rather than shipping the raw materials elsewhere.

Kropff: Exactly. We've been doing more work on this in the last ten years. Cimmyt works on wheat and maize, and these are products that need to be processed. Doing this locally would also help people save food in the future for more difficult times, instead of selling to someone from the city who may buy it at an unfair price. Farmers these days have access via smartphones to market information, which is empowering. We see it happening in Africa. It's really crucial.

Nicholls: We're certainly seeing the power of digital technologies, which are also helping us move beyond just responding to crop pests and diseases to being able to get better at predicting outbreaks on a micro-scale. By linking ground observations through our Plantwise clinics with satellite observation technology and data, we've developed a programme called Pest Risk Information Service or Prise, which provides farmers with alerts before a pest is likely to reach its peak point, so that they can be prepared and take preventative measures.

Kropff: Without a doubt, smallholder farmer communities are rapidly entering the digital age, and tools on weather prediction, selection of varieties and market information are very important, and are transforming the way people farm.

...ON CLIMATE CHANGE

Kropff: Climate change is going to be the issue affecting family farmers, especially in Asia and Africa, where the population will grow by two billion people who need food that has been produced on their own continents. Yields have to rise and climate change brings yields down. We have to help smallholder family farmers keep doing their job and ensure crop yields, which is why climate change is embedded into 70 per cent of our work at Cimmyt. One major area is developing and testing heat and drought-tolerant varieties that suit local climates. Last year I was in Zimbabwe, which was experiencing El Niño, and I was very impressed by the difference in maize yields from drought and heat-tolerant varieties compared to the normal varieties.

Nicholls: That's very good. In addition to drought and heat, we see pests and diseases appearing in new places as a result of climate change. Pests and diseases will cause crop losses of up to 40 per cent on average. Stemming those losses is critical. We're seeing invasive species, such as the fall armyworm, and many invasive weeds and trees that are effectively stealing arable and pastoral land, as well as water resources, from farmers.

Pest-resistant crops have great long-term potential, but farmers also need short-term solutions while they wait for new varieties to become available. One of Cabi's strengths is scanning for solutions from other parts of the world. With the fall armyworm, we are looking to South America, where the pest originates, for solutions and natural enemies. We're also scanning our fungal culture collection for samples that may have properties that can form the basis for biopesticides, and therefore open up a programme of biological control.

HOPES FOR THE FUTURE

Nicholls: I'm very optimistic for family farmers. They are incredibly resilient and resourceful people, and they survive and thrive in pretty difficult circumstances. But the world is getting more challenging for them by the day. I think the SDGs – the Sustainable Development Goals – have framed many of the issues very well, in terms of food security and livelihoods, sustainable consumption and production, and this will help to focus attention on family farmers.

I do see some quite encouraging signs, particularly in Africa, where the CAADP – the Common African Agricultural Development Programme – has brought much greater coordination among countries. We're witnessing more unity in the requests we receive from our member countries to help them address the issues that are in the SDGs. That makes the work of our organisations easier, because we're addressing a broader set of demands. And in turn, that will benefit family farmers.

Technology, be it biotechnology or telecommunications and ICTs, is becoming so much more affordable over time. The rate that smartphone usage is spreading in Africa and Asia is incredible. In many areas we actually have most of the technology we need today. What's needed is getting larger numbers of farmers to apply it effectively. So I remain very optimistic about the future.

Kropff: I'm an optimist by nature. That's also why I'm in this job: it's not easy, but I really believe that change is possible if we have our act together and collaborate with Cabi and other international research partners, national systems and the private sector. For a long time, people said that there was no Green Revolution in Africa, where yields remained one ton per hectare. But today we see yields increasing in countries such as Nigeria, and in Ethiopia, where maize yields are 3.5 tons per hectare. Good things are happening because of family farming.

I believe that to increase yields you need three components: better seeds for more resilient crop varieties; sustainable intensification to grow more nutritious food per unit of water, land and soil; and good governance, to properly manage resources. We need to invest in all of these areas.

Nicholls: I fully agree. We need to work on all these areas, and harness the power of modern technology to help family farmers thrive now, and in the future.

For references and further reading, see online version of this article at: **www.rural21.com**

HOW 'SUPERMARKETISATION' AFFECTS NUTRITION AND HEALTH IN KENYA

Many African countries are experiencing a rapid spread of modern supermarkets. This "supermarket revolution" is changing food environments in terms of food variety, prices, processing levels, packaging sizes, and shopping atmosphere. A research study in Kenya has analysed the effects of supermarkets on adult and child nutrition in urban areas.

By Matin Qaim

In many African countries, supermarkets are spreading rapidly, complementing and partly replacing traditional food markets and grocery stores. Compared to traditional markets, supermarkets offer a wider variety of processed and highly processed foods and beverages, often in larger packaging sizes and combined with special promotional campaigns. Hence, one important question is whether the spread of supermarkets contributes to rising overweight and obesity. While in the past, overnutrition was primarily a problem in rich countries, obesity rates in low- and middle-income countries are rapidly catching up. Obesity is associated with a number of chronic diseases – such as diabetes, cardiovascular problems and certain forms of cancer – that African health systems are not well prepared to deal with.

Compared to traditional markets, supermarkets offer a wider variety of processed and highly processed foods and beverages, often in larger packaging sizes and combined with special promotional campaigns.

Photo: LAIF

TAKING STOCK IN KENYA

Analysing the effects of supermarkets on diets and nutrition is not easy, because of many possible confounding factors that need to be controlled for. In our study, we focused on medium-sized towns in Central Kenya, some of which already have a supermarket while others have not. We randomly selected around 500 households in different towns. In these households, we collected comprehensive socioeconomic, nutrition and health data (e.g. dietary intakes, weight and height measures, blood samples) at household and individual levels for adults and children. A first round of data collection was conducted in 2012, and a second round three years later. The Figure on page 26 shows that the body mass index (BMI) among adults in the study sample, as well as overweight and obesity rates, increased considerably between 2012 and 2015.

The observed rise in overweight and obesity may be attributable to supermarkets, even though other factors – such as differences in income or physical activity – might also play an important role. To analyse whether shopping in supermarkets really contributes to rising BMI and obesity, we used panel data regression models and controlled for possible confounding factors.

RESULTS FOR ADULTS

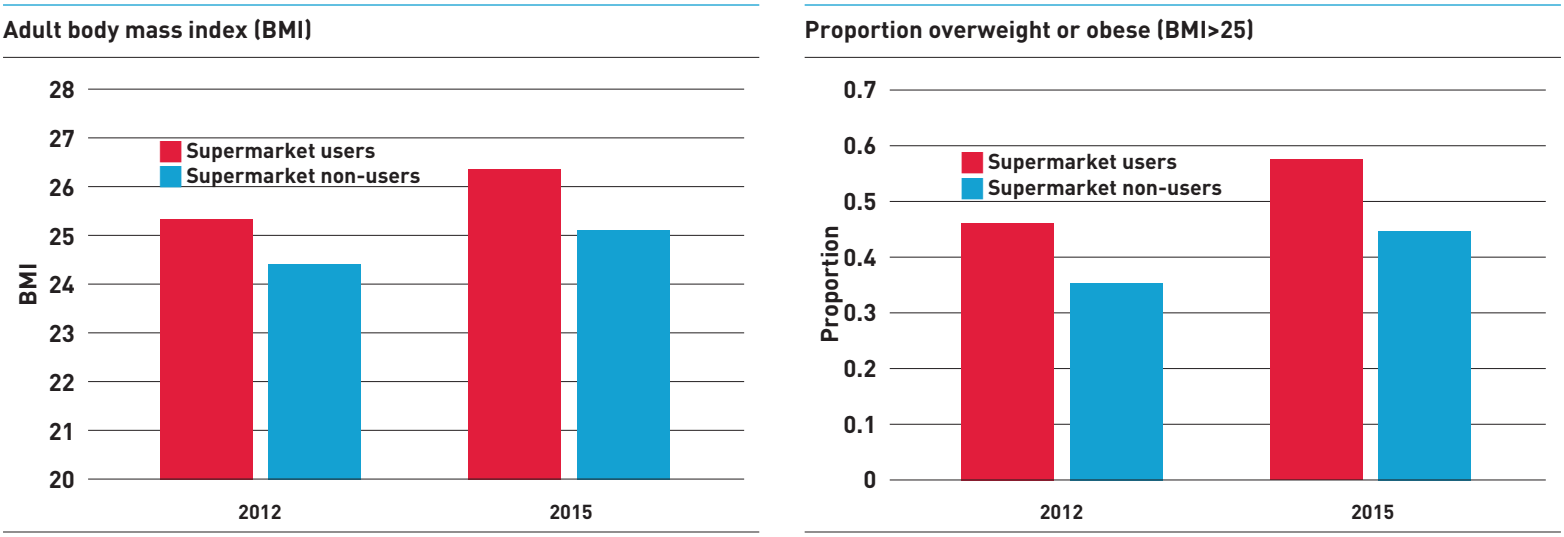
Results suggest that supermarkets increase adult BMI, also after controlling for household income, age, education, physical activity and various other factors. The estimated net effect of using supermarkets instead of traditional markets is an increase in BMI by 0.64 kg/m^2. The data also show that shopping in supermarkets increases the probability of being overweight or obese by seven percentage points and of suffering from diabetes or pre-diabetes by 16 percentage points, which are quite sizeable effects.

The negative impacts of supermarkets on consumer nutrition and health can be attributed to the fact that the average price per calorie of food purchased in supermarkets is lower than in traditional markets. Cheaper calories contribute to higher calorie consumption, which may improve food security for households that suffer from calorie undersupply. However, especially in urban areas, overweight is now often more prevalent (>40% in Kenya) among adults than underweight (<5%), so that more calories further aggravate the problem of overnutrition. In addition, supermarket shoppers often consume more processed foods, including semi-processed items as well as highly processed foods and snacks. Highly processed foods in particular tend to contain a lot of sugar, fat, and salt, all of which can be associated with obesity and chronic diseases when consumed in excessive quantities.

RESULTS FOR CHILDREN

The results discussed so far refer to adults. Strikingly, our data from Kenya show different effects on children. While supermarket shopping contributes to weight gains among both adults and children, for children this does not yet seem to have negative health effects, mainly because overweight rates are still much lower for children than for adults. In Kenya and many other African countries, childhood undernutrition is still more prevalent (>20%)

Adult nutritional status of supermarket users and non-users in Kenya, 2012-2015



than overnutrition (<10%), which is also reflected in persistently high rates of child stunting (low height-for-age).

Our data from Kenya demonstrate that supermarket shopping contributes to an average gain in child height of about 2 cm, also after controlling for other factors. The positive effect on child height is larger than the effect on child weight. Robustness checks showed that these results were consistent for children below and above five years of age. This is a welcome finding, implying that the spread of supermarkets may possibly help to reduce issues of child stunting. At the same time, supermarkets do not (yet) seem to be a driver of childhood obesity in Kenya.

The positive effects on child height may come as a surprise under the common assumption that supermarket foods add to calorie consumption but not to dietary quality. As commonly known, childhood stunting is closely related to low dietary quality and micronutrient deficiencies. However, our data show that supermarket shopping in Kenya actually increases dietary quality. We found significantly positive effects on dietary diversity and also on the likelihood of consuming certain healthy food groups that are rich in micronutrients, such as fruits, meat, fish, and eggs. Positive effects of supermarkets on dietary quality were also observed after controlling for household income, education and other possible confounding factors.

More consumption of processed foods and better dietary quality are not necessarily contradictions. While highly processed foods are often dense in sugar, fat and salt, semi-processed foods can also involve items such as canned or preserved fruits, vegetables, and animal products with higher amounts of micronutrients. Especially for low-income households, food processing and preservation may allow more regular consumption of certain nutritious foods that are less accessible in fresh form because of their perishability and resulting higher prices.

DIFFERENCES BETWEEN ADULTS AND CHILDREN

That supermarkets in Kenya contribute to rising obesity in adults but not in children is interesting and plausible. Adults cannot grow in height anymore, so additional calories and nutrients from supermarket purchases will primarily lead to increases in body weight. In situations where average BMI levels among adults are already high, as is the case in urban areas of Kenya, additional weight increases will inevitably contribute to rising rates of obesity. For children, this is different. First, as children are still growing, additional calories and nutrients can contribute to gains in height, as we observed in our study. Second, in most situations, overweight and obesity rates are still much lower in children than in adults, meaning that moderate weight increases in children do not necessarily drive up child obesity rates. Third, adults in urban environments typically have lower levels of physical activity than children. As is well known, sedentary lifestyles and limited physical activity are also important drivers of overweight and obesity.

WIDER IMPLICATIONS

The results from Kenya are interesting but should not be generalised. The nutrition effects of supermarkets will depend on the initial dietary and nutrition situation and the types of dietary shifts that occur. In the medium-sized towns in Kenya, many of the households are still moderately poor, and traditional diets are not highly diversified. In this context, the greater variety of foods offered by supermarkets at affordable prices can improve diets and nutrient intakes, even when most of the products purchased in supermarkets are in processed or semi-processed form. The nutritional effects could be different in settings where households are already richer, diets are more diversified, and supermarkets primarily add to the consumption of highly-processed snacks and convenience foods. In such cases, supermarkets could contribute to obesity among both adults and children.

The study findings suggest that the effects of supermarkets on people's diets and nutrition are complex and context-specific. Supermarkets are rarely the only source of food purchases for consumers. As a new retail format that complements other food markets and shops, supermarkets seem to improve people's access to food calories and diversity, which as such is positive. Higher consumption of ultra-processed foods, in turn, can be negative from a nutrition and health perspective. More research is needed to better understand the effects of supermarkets and other changes in people's food environments on individual diets and nutrition in different situations. This knowledge is required to design appropriate food and nutrition policies and regulations that may be needed to avoid undesirable health outcomes.

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