United Nations Food Systems Summit 2021
Scientific Group Scientific Group
https://sc-fss2021.org/

Food Systems Summit Brief
Prepared by Research Partners of the Scientific Group for the Food Systems Summit
April 2021

The Role of Science, Technology, and Innovation for Transforming Food Systems in Asia.

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Abstract

This brief focusses on the role of science, technology and innovation (STI) in transforming the food systems of Asia and the Pacific to achieve long-term environmentally sustainable food and nutritional security, and draws upon the findings of a recent Association of Academies and Societies of Sciences in Asia (AASSA) Working Group. The Working Group included scientists appointed by the respective academies and from across the region and representing different relevant scientific disciplines.

The Working Group recognised that a "whole of systems" approach is required to address the issue, and that work is urgently needed to define 'healthy' diets for different regions, societies and cultures. Emphasis should shift from the provision of calories, to the supply balanced patterns of all the essential nutrients, and the 'holistic' properties of foods should be recognised.

The AASSA study identified countries and regions, within Asia, considered to be at particularly high risk for future food security. It was urged that systems analysis

be applied across the agricultural and food sectors of these countries to identify the actual technical and other impediments to food and nutrients supply. It was envisaged that the results from such an analysis would be used to formulate a 'blueprint' for agricultural and food STI in Asia.

Overarching recommendations were the establishment of a trans-national funding mechanism for the entire region focussing on targeted inter-disciplinary STI, and the establishment of regional Centres of Excellence for research, education and extension focussing on the identified key areas of opportunity.

It was concluded that there is an urgent need for investment and action.

Introduction

It is now widely accepted that there is an imperative to transform food systems to provide guaranteed supplies to all of nutritious, healthy foods that are produced and distributed in a sustainable manner, for a rapidly growing world population (Committee on World Food Security (CFS), 2019; FAO and WHO, 2019; Fanzo *et al.,* 2020a; Global Panel on Agriculture and Food Systems for Nutrition, 2020; GNR, 2020; International Food Policy Research Institute (IFPRI), 2020a).

A consensus view is one thing, but what is now required is **Action**.

This briefing document focusses primarily on the role of science, technology and innovation (STI), and including research and development (R&D), education and extension, in transforming the food systems of Asia and the Pacific. The briefing draws heavily on the IAP report published in 2018: "Opportunities and challenges for research on food and nutrition security and agriculture in Asia", but updated to included new perspectives. The Working Group responsible for the latter report was convened under the auspices of the Association of Academies and Societies of Sciences in Asia (AASSA). The approach was a "bottom-up" analysis of projected food and nutrition security in the region with respect to population growth and related demographics, projected regional trends in malnutrition in all its forms, climate change, resource depletion, biodiversity loss and environmental degradation. Experts from science academies across the region made up the Working Group, and each expert provided information and insight for their country or region. This allowed synthesis of the material to allow common themes to be developed and general as well as specific conclusions to be made. A strength of the inter-science academy approach was that expertise from a broad range of relevant scientific disciplines from across a wide geographical area, was drawn upon. This allowed the identification of scientific and technical issues and opportunities not only at global and regional levels, but also at a national and sometimes sub-national level, reflecting the great diversity between and within countries, sectors and populations.

1. The overarching framework for developing inclusive, sustainable food and nutrition systems.

Globally, a considerably greater quantum of food and a more diverse array of food types, needs to be produced and distributed equitably to ensure a balanced diet to adequately nourish a projected population of around 9 million persons by year 2050. This is against a current backdrop where around 1 billion people are undernourished, many more suffer from 'hidden hunger' whereby they receive inadequate amounts of vitamins and minerals, and where in many countries, there is an escalating prevalence of obesity and the metabolic syndrome.

This required increase in the production of foods must occur in the face of several constraints. The land area available for agriculture is unlikely to increase in the future and may well decline because of the demands of urbanisation, conservation, bio-ecology and land loss from sea-level rises caused by global warming. Limitations in the supply of other vital resources (e.g. fossil fuels, fertiliser and water) are also likely to pose a challenge. Future food increases will need to be sustainable, environmentally, economically, culturally and socially, and will occur in the face of unpredictable outcomes that are consequent upon climate change. The 17 Sustainable Development Goals adopted by the United Nations in 2015 offer an important framework for addressing the challenge of the global food supply but, if these goals are to be met, evidence-based science will be a necessary prerequisite.

The production and supply of food follow a complex web of interacting processes and systems. Agriculture and food production are part of a widely interconnected multi-functional landscape or agri-ecosystem (German *et al.,* 2017). To achieve sustainable production, the wider ramifications of changes to the systems need to be assessed and understood and inevitable trade-offs reconciled.

A systems analytical approach is paramount to identify impediments to FNS and to provide workable holistic solutions. A wide range of both technical and non-technical (including purchasing power, barriers to trade, capital investment, infrastructure, government policies, cultural mores, demographic shifts, political and social stability, equity of access, gender equality and education) factors is relevant. Not wishing to undermine the importance of these non-technical factors, it is beyond doubt that science, technology and related innovation (SIT) will be critical in addressing FNS. The production of food in a sustainable manner, the processing and storage of food, the minimisation of food wastage and the development of healthy diets adapted to local conditions and populations are of paramount importance. The application of current scientific knowledge through improved education and extension practices, the development of new scientific knowledge in targeted areas and related technology developments will all be essential in terms of meeting the global food challenge.

In the AASSA (2018) report on FNS for Asia, the need to focus STI efforts to provide high quality relevant evidence was emphasised, a contention echoed recently by the Committee on World Food Security (2019) and Fanzo *et al*. (2020b).

The approach taken by the IAP Working Group was to use national and regional statistics for Asia and the Pacific on projected population growth, population age distributions, economic development and current estimates of under- and over-nutrition to allow a focus on countries and geographical areas that are most likely in the future to face the harshest FNS issues. A strategy moving forward would be to use 'systems analysis' to identify key impediments to FNS in these areas and to use such analysis to prioritise extension, education and research and development (Stathers *et al.* 2020; Ricciadi *et al.* 2020). The report emphasises the need for a territorial dimension in such an analysis, recognising often profound differences between geographical areas and socio-economic groupings. The territorial approach to investigating FNS implies a shift from a sectoral (usually agricultural production), top-down, 'one-size-fits-all' approach to one that is multi-sectoral, bottom up and context specific. Food systems must be inclusive of marginalised people and small holders (IFPRI, 2020) as should STI and education.

The work has identified several countries within the region that are at high risk for future FNS. Countries such as India, Bangladesh, Pakistan, Afghanistan, Nepal and Myanmar as well as the Philippines, Tajikistan, Iraq and Yemen are deemed to be particularly high risk countries for future FNS. This is not to say that other countries in the region are free from future issues concerning FNS; rather, it gives a rational starting point as to where work may be most effective.

There is no doubt that the global and Asia food supply will be required to increase significantly over the next three decades. The required increase in net food supply may involve reducing food wastage and effects on the demand side brought about by changing food consumption patterns, but will also involve producing more food from existing agricultural land. This will involve both closing existing yield gaps and increasing food production from land that is currently considered to be yielding at a high level, through further intensification. Intensive agricultural production is already associated with environmental costs, however, through side effects such as nutrient runoff and eutrophication of waters, greenhouse gas (GHG) emissions, soil erosion and soil degradation, as well as resource costs such as depletion of water and fertiliser reserves. Future farm production will be expected to reduce these negative environmental impacts. 'Sustainable intensification' will be required, and this will require a step-change in STI (Pretty et al., 2010; Parker et al., 2014). China is already making progress in this domain (Cui *et al.,* 2018) Clearly, increased production per plant or animal, in a sustainable manner is beneficial in that it reduces the amount of waste material (e.g. methane) per unit of production (e.g. kilograms of grain or kilograms of meat). Over recent years there has been a renewed interest in bioecological agriculture and circular agriculture, where an ecological harmony is sought, and resource use is optimised and solid wastes and gaseous emissions are minimised due to capture and re-use. Research in this direction is encouraged, though it is recognised that bioecological agriculture and intensive farming are not mutually exclusive systems. Traditional mixed framing models of intensive agriculture may already incorporate principles inherent in bioecological farming (eg crop rotations, animal/crop/pasture balance, the use of tree shelter belts, nitrogen fixation via leguminous crops and clovers, minimal tillage, integrated pest management).

Although the IAP Working Group strongly promoted the clear identification of gaps in knowledge, currently creating impediments to lifting and diversifying food production, as a critical starting point for renewed and refreshed STI effort, they also recognised that there are certain areas of contemporary science, whereby investment in R&D is likely to yield immediate and widespread dividends. These areas included: (1) sustainable farming practices addressing wider issues such as biodiversity, land and water degradation and climate change which would include bioecological approaches; (2) genomic-based approaches (including molecular markers for selection and CRISPR/Cas9 technologies) to plant and animal breeding; (3) 'big data' capture and analysis, precision agriculture, robotics, artificial intelligence; (4) Food technology innovations in harvesting, processing and storage to reduce wastage, and promote more equitable distribution of safe non-perishable food and lead to healthier processed foods; (5) Aquaculture production and integrated farm production systems.

2. Delivering Healthy Diets

In achieving FNS in the future, calorie provision alone will not be sufficient. Rather it will be required to provide a broad range of diverse foods so as to meet the requirements for all of the dietary nutrients, and non-nutrient food components known to influence human health. Just what constitute a healthy diet is a 'moving target', and research is required to establish scientifically what constitutes healthy diets for different socio-cultural groupings and regions. Currently, for example, there is controversy over the role of saturated fats in health (Bier, 2016) and over the risk of consuming unprocessed red meat for the development of bowel cancer (Alexander and Cushing, 2011).

The classical approach in nutritional science has been reductionist, whereby the nutrients found in foods are considered the fundamental unit of nutrition. This concept has been challenged more recently, and considering the clearly important 'holistic' properties of foods, it has been suggested that a food should be considered as the fundamental unit of nutrition (Kongerslev, *et al.,* 2017). A better scientific understanding is required of the nutritional and health effects of the interactions of structures within complex food matrices and among foods when mixtures of different foods are eaten together. With such knowledge there is an opportunity to manufacture healthier foods. During traditional manufacturing natural food structures are often degraded, and new structures potentially with less desirable properties, formed. New approaches to food manufacturing are needed to ensure the provision of food matrices, food nutrient contents and food bioactives that are consistent with health. The food industry is clearly a powerful medium, for the manufacture and distribution of healthy foods and the way forward will be cooperative research programmes between agricultural sectors, food companies, universities and government funded research organisations to explore new processing technologies with the aim of shifting the food supply towards nutritious healthy foods and diets.

Having accurate information on the amounts of dietary nutrients required to support body processes and long-term health (dietary requirements) is insufficient. Foods also contain many compounds that are not classically viewed as nutrients (eg phytochemicals, bioactive proteins and peptides, and fibre), but may have important effects upon human health. Examples, among many, are immunoglobulins in milk, probiotics in yoghurt and other fermented foods, catechins in tea, bioactive peptides released from many proteins, flavonoids in cocoa, and tannins and anthocyanins in fruits and berries. These properties of food need to be much better understood, and should be the focus of STI. Moreover, the role of diets in influencing gene expression in humans (nutrigenomics) and how genetic makeup influences dietary effects on physiology, metabolism and health (nutrigenetics) offer great potential for a better understanding of nutrition and its influence on health, and pave the way for personalised nutrition (Fenech, 2008). It is important to recognise that it is not only the human genome that is influenced by and influencing nutrient uptake and metabolism, but the numerous genes of the prolific gut microbiome undoubtedly have a major influence on nutrient utilisation, metabolic outcomes and health. This is a fertile area for further research and highlights again the complexity of the influence of diet on human health.

There is much evidence that often poor nutritional choices are made at the point at which foods are selected for consumption, and better education at all levels on the impact of food and nutrition on health is critical. Sociological and behavioural research is required to better understand the purchasing motivation of people of different ages and socio-cultural backgounds. Foods must be desirable, and equally STI is needed to ensure the wide availability of foods that are not only nutritious and healthy, but are also safe, convenient, and that have great taste, texture and other properties. Food science and technology, including sensory science, have a major role to play.

In the IAP study particular attention was given to the Hindu Kush Himalayan (HKH) region, a vast area of land extending 3500 km across the high mountain regions of Afghanistan, Bangladesh, Bhutan, China, India, Nepal, Myanmar and Pakistan. Malnutrition and hunger are widespread in the region and a complex interaction of socio-economic, environmental (including food production systems) and cultural factors is considered to be the cause of the widespread malnutrition.

The mountain areas have a low 'carrying-capacity' for agricultural production, and cropping systems have been reliant on diverse traditional crop varieties. However, rapid socio-economic change has led to changed land use, changed crop varieties and new food consumption patterns. The planting of nutritious traditional crops, such as amaranth, buckwheat, minor millet, finger millet, proso millet, foxtail millet, sorghum, barley and sweet potato, is declining; these crops are being replaced by higher-calorie-yielding crops such as rice and wheat, leading to a decline in agro-biodiversity. The production of traditional crops is declining because of factors such as a lack of awareness of their nutritional value, a lack of local markets for the produce and an increasing demand for crops such as rice, wheat and maize. There has been a shift in foods from home-grown foods to purchased foods, from coarse-grain foods to fine-grain foods and from traditional snacks and drinks to potato chips, instant noodles and soft drinks (Rasul et al., 2017). The consumption of the traditional coarse grains is often viewed as backward in the new value system.

The trend by the urban poor away from legumes and coarse grains, and towards the consumption of oils, fats and high-sugar products, is not unique to the HKH region but is general in both China and India (Du et al., 2002).

Further, there would appear to be much scope for encouraging farming programmes among smallholder farmers that aim to diversify diets and improve nutrition. Such programmes (Girard *et al.,* 2012) aim to increase household production of perishable nutrient-rich foods (e.g. fruits, eggs, meat, fish and milk). The production of such foods on the farm makes them accessible and less vulnerable to storage and transport losses. Such an approach has been shown to diversify the diet of often nutritionally vulnerable smallholders (Iannotti *et al.,* 2009).

3. Transformation to sustainably produced and healthy diets

Not only must the diets of the future be healthy, but they must also be sustainably produced. A new approach is needed to design, evaluate and monitor diverse farming systems. The complexities of diverse farming systems need to be recognised and a nuanced approach taken (Global Panel on Agriculture and Food Systems for Nutrition, 2020). By means of example ruminant livestock farming makes a major contribution to GHG emissions, but at the same time livestock farming is economically and culturally important to many people. Also meat and milk are of high nutritional value and an important supply of minerals (such as calcium, zinc and iron) and vitamins, such as vitamin B12. Whereas a case may be made for the inefficiency of feed-lot cattle production (Poore and Nemecek, 2018), the same is not necessarily the case for large amounts of pastoral cattle production (Adesogan *et al.,* 2019). Moreover, meat and milk are primarily produced to provide amino acids, minerals and vitamins for human nutrition. When GHG emissions from meat and milk production are expressed per unit first-limiting amino acid rather than per unit total protein such production is seen in a new light (Moughan, 2021). Recent modelling using Linear Programming demonstrates, that given current price relativities, that animal-based products are needed to provide least-cost diets (diets that meet all nutrient requirements at the lowest cost) (Macdiarmid *et al.,* 2012; Chungchunlam *et al.,* 2020). It would appear that the cost of some animal products would need to increase greatly, before they would no longer be found in a least-cost diet. Sustainable diets must be affordable. The issue is nuanced, and entrenched "blanket" positions should be avoided. The development of new farming systems (eg insect, algae, single-cell food production, and *in vitro* meat production and biotech foods) should be encouraged and their integration into the more traditional land-based systems carefully assessed.

The expansion of aqua-culture will likely occur in the future, and STI is needed to improve the genetics of farmed fish and crustaceans, as well as developing systems that mitigate against eutrophication. A key target in developing more sustainable farming systems will be the reduction of food/nutrient wastage, and here food science STI has a vital role to play. The DELTA Model (https://sustainablenutritioninitiative.com/) has recently been developed and calculates nutrient availability to consumers from differing global food production scenarios. Early findings from the model indicate that global food production currently supplies sufficient macro- and micronutrients to nourish the global population if equally distributed, with the exception of calcium and Vitamin E. These nutrients appear to be undersupplied by at least 30%. Total removal of food waste from the model although helpful does not solve these insufficiencies. Nutrient loss due to food waste is not constant across all nutrients: relatively little calcium and vitamin E is wasted, whereas waste of carbohydrates and protein is high. Further, while the current food system would provide sufficient energy and protein for the forecast 2030 global population of 8.6 billion, it would fail in supplying several micronutrients (calcium, iron, potassium, zinc, riboflavin and vitamins A, B12 and E).

4. Addressing food-energy-water nexus and other natural resources

The AASSA working group addressed land use for food production in light of competing interests (eg urbanisation, textiles, biofuel, ecological restoration, recreational use). An evidence based and total systems based (accounting for the principles of re-cycling and circular agriculture) approach is urged to ensure planning to make optimal use of limited land, water and other resources.

5. Supporting and using outputs from fundamental research

Although the role of applied science, technology and extension is likely to be pivotal in solving key issues, the potential for 'game-changing' new discoveries arising from fundamental science should not be overlooked. Recent-past discoveries in molecular biology, IT, cell biology serve as shining examples of the power of 'unfettered' scientific endeavour. Strong programmes in fundamental science are encouraged. At the same time, well-targeted applied research programmes will need to place less emphasis on increasing plant and animal production *per se*, and will need to seek to optimise agricultural outputs in face of multiple externalities. Cross-disciplinary systems research, bioecological farming, and farm management science will all be important.

6. Consequences of Covid-19

The Covid-19 pandemic has highlighted the vulnerability of global food systems (eg rising unemployment and loss of purchasing power, loss of seasonal labour, disruption of food processing and food distribution). Global food systems need to be resilient (International Food Policy Research Institute (IFPRI), 2020b; Di Marco *et al.,* 2020). The pandemic further highlights the role of good nutrition and healthy diets in supporting the immune system (Calder, 2020).

7. Strengthening Policy for Research and its Uptake

Planning for and securing FNS in Asia will require dedicated and bold commitment from politicians and policy makers, while scientists in the region have the responsibility to provide robust peer-reviewed scientific knowledge, to allow evidence-based decision making.

The AASSA Working Group urged the establishment of a trans-national funding mechanism in the region (similar to that in the European Union), focussing on inter-disciplinary FNS STI. Considering the often considerable lag time in research between investment and adoption, it is imperative that governments in the region not only maintain support for R&D, education and extension related to FNS, but also greatly increase, as a matter of urgency, the overall level of funding. Funding in agriculture and related disciplines has declined over recent decades (AASSA, 2018). There needs to be a considerable resurgence in agri-food R&D, extension and education, and such an emphasis needs to be more cross-disciplinary and systems oriented than in the past. Several areas of STI are seen as universally important for the region (see earlier section), and it is strongly recommended that a cooperative regional approach be taken, to form well-resourced regional centres of excellence that focus on key areas of opportunity.

The importance of formulating an evidence-based 'blueprint' for FNS R&D in the region is stressed. If progress is to be maximised funding needs to be carefully targeted. Systems research needs to be applied, early on, to identify critical impediments that currently affect the region's ability to increase food production sustainably and to ensure a diversity of high-quality foods reaching the consumer. The knowledge generated must be communicated rapidly, and shared freely and extensively. In addition to a ramping up of R&D effort, funding should also be allocated to education at all levels and to "on-farm" and "in-factory" extension. Over and above regional cooperative STI initiatives, there is much opportunity for accelerated collaboration through targeted global alliances, and national/regional policies should incentivise this. A lesson from Covid-19, is that with restricted travel, the necessary IT infrastructure needs to be in place and available to all to allow unimpeded collaboration across boundaries and borders. Networking will be paramount.

Ongoing support for international STI programmes such as CGIAR, IFPRI and ICARDA is urged, as is the incentivisation of public-private partnerships (Fanzo *et al.,* 2020b).

In formulating an STI strategy for the region, the potential power of fundamental science should not be ignored. Discoveries, often arising from fundamental science, have the capacity to lead to step-changes in agricultural productivity. Examples of emerging disruptive technologies are found in bio-based manufacturing to produce fuels, chemicals and materials through advanced, efficient and environmentally friendly approaches. Synthetic approaches to producing animal-free meat and milk have attracted much attention. Such products may have advantages in cost of production, ethical acceptance and sustainability, but consumer acceptance is yet to be tested.

Agricultural and rural development were priorities for foreign aid and international development banks before the mid-1980s, but investment in this area has declined in subsequent years. Agriculture and food have been off the global development agenda and this must be reversed.

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This Brief was prepared for the UN FSS by updating the AASSA scientific assessment contributed to the IAP project on Food and Nutrition Security and Agriculture.

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This report presents an update and summarised version of the report *Opportunities and challenges for research on food and nutrition security and agriculture in Asia.*
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