Crops For the Future

DIETARY DIVERSIFICATION FOR ENHANCED HUMAN NUTRITION

The role of underutilised crops

This policy brief explains how consuming a diverse range of plants can improve the nutritional quality of the human diet, and contribute to improved health and livelihoods. It provides evidence to support policies that encourage the consumption of currently underutilised crop plants.

Introduction

Our food systems are currently dominated by four crops – rice, maize, wheat and soybean – of which the three cereals provide over 50% of plant-based human food (IPES-Food 2016). Over the last 50 years, production of the three main cereals (rice, maize and wheat) has more than tripled in contrast to that of many other crops (Godfray et al., 2010), so that food systems have become relatively more dependent on a few crops. Reliance on a few crops to not only feed but nourish the growing global population, in the changing climates of the future, is also a major threat to ensuring global food and nutritional security, in particular in sub-Saharan Africa.

Deficiencies in key vitamins and minerals pose a very serious constraint to human health and economic development as detailed by the GLOPAN Foresight Report (GLOPAN 2016). This Report, together with the Global Nutrition Report (IFPRI, 2014) and the Kigali Declaration on Biofortified Nutritious Foods (HarvestPlus 2014), highlights the need for multiple complementary strategies to address key micronutrient deficiencies.

The GLOPAN Report (2016) highlights that healthy diets comprise a diverse variety of fruits and vegetables, wholegrains, fibre, nuts and seeds, whilst limiting free sugars, sugary snacks and beverages, processed meats and salt.

Many plants contain higher concentrations of vitamins, mineral nutrients and phytometabolites than found in cereals, so that consumption of a diverse range of plants is beneficial to human health (Boedecker et al., 2014). Fruits, vegetables and other plants rich in minerals and vitamins can be grown in diverse cropping systems to complement the major crops, thereby improving diets and human health. Smallholder producers in both rural and urban areas frequently grow a mix of plants to enhance their diets. Women play a vital role in producing such plants and as urbanisation increases, the peri-urban production of crops such as vegetables, fruits and herbs increases in importance.

Insufficient calories
Insufficient nutrition

1 BILLION

Sufficient calories
Sufficient nutrition

3 BILLION

Sufficient calories
Insufficient nutrition

2 BILLION

Excess calories
(including some with
insufficient nutrition

2.5 BILLION

Dependence on a small number of cereal crops has led to increasing concerns about human diets being energy rich but nutrient poor (Stadlmayr et al., 2011; Toledo and Burlingame, 2006). Micronutrient deficiencies are now recognized to be more widespread than energy/protein malnutrition with at least 1.5 billion people likely to be affected by one or more micronutrient deficiency (GBD, 2016). Such deficiencies exist in populations even where the food supply is adequate in terms of meeting energy requirements but are most prevalent in areas where the diet is monotonous and lacks diversity, a situation that is the norm in many developing countries. The most vulnerable groups are women and children of all communities, and displaced individuals, such as those escaping persecution and discrimination in war torn countries (Kennedy et al., 2003).

Combinations of actions are needed to secure better diets because different populations within a country can only be reached by different methods. The GLOPAN policy brief on Biofortification (GLOPAN 2015) outlines one such promising strategy to enhance the availability of vitamins and minerals for people whose diets are dominated by micronutrient-poor staple food crops.

A complementary and equally valid strategy is that of dietary diversification through the increased consumption of a variety of whole foods.

Food based solutions (for diversifying both agriculture and nutrition) have immense potential to alleviate hidden hunger. Diversification of the diet, to include foods from a range of sources, in particular from underutilised species, is one such approach that is addressed in this policy brief.

It can be implemented by all population groups, especially subsistence farmers in both rural and urban settings, who have the skill and capacity to diversify their production to include a range of fruits, vegetables, nuts and berries.

This policy brief sets out the arguments for expanding support for research into currently underutilised crops that could provide major nutritional benefits to human diets and the associated livelihood benefits to marginal farmers, processors and marketers.

Publication of the brief is timely as it concurs with the key messages of the GLOPAN Foresight report on food systems and diets – to diversify both agriculture and nutrition in order to achieve healthy diets. A refocussing of global food policies to ensure quality not quantity of food produced with the aim to achieve nutritional security rather than food security. Momentum is building amongst the key players – Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO) - to enable this shift in focus. The publication of this Brief coincides with the FAO proposed 'Year of Forgotten Foods', which follows on from the 2016 International Year of Pulses. Policy makers at FAO and globally recognise that beans, lentils and chickpeas are among the plant species that will help achieve the Sustainable Development Goals (FAO.org, 2017).

Research on food, agriculture and nutrition must be refocussed on achievement of healthy diets

GLOPAN Foresight Report (2016)

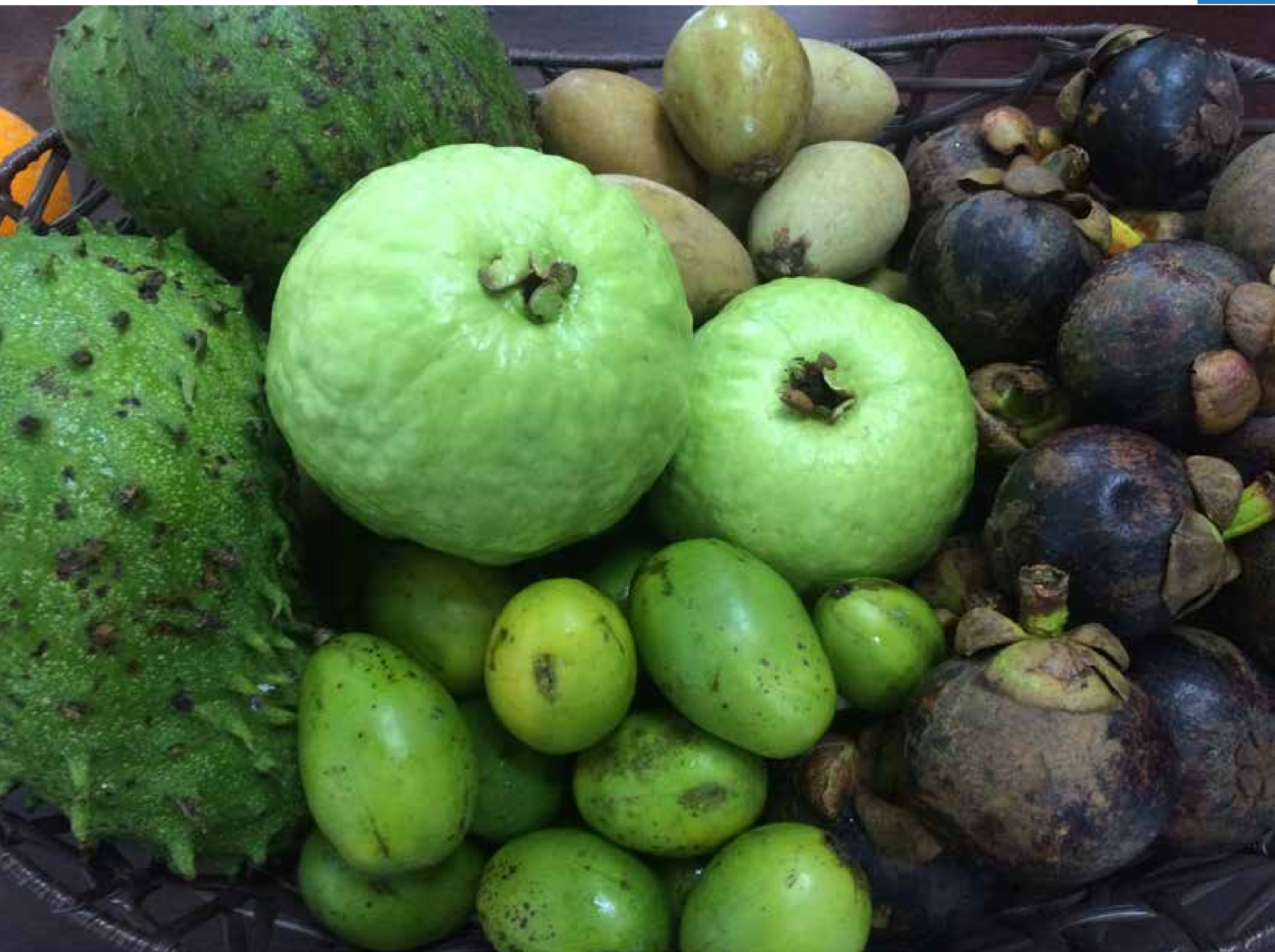
Why underutilised crops?

Underutilised crops comprise the multitude of species that are currently largely neglected by major research and funding bodies. They include cereals, grains, legumes, fruits, vegetables, flowers, roots, seeds and nuts. Although these species have long been overlooked, interest is growing in their potential to contribute to food and nutritional security and improved livelihood options for subsistence farmers, a large proportion of whom are women.

Some of these underutilised species can yield under a range of soils and climates that are hostile to, or unfavourable for, production of the more common staple crops. For example, millet species typically yield in marginal soils and climates in India and African countries (Handschuch and Wollni, 2016; Jukanti et al., 2016). This is of obvious benefit for the changed climate expected over the coming decades. Some yield of a diverse range of nutrient rich plants is nutritionally superior to no yield of a current staple crop.

The human need for minerals, vitamins and phytometabolites

For optimal health and nutritional status, humans need to consume a range of macro and micro-nutrients, including essential amino acids and fatty acids, vitamins, minerals and plant derived bioactive compounds.



Nutritional benefits from consuming underutilised crops

Consumed together with staples, underutilised species can complement and diversify the diet with a range of micronutrients and bioactive compounds essential to health. These include:

Amino acids

The essential amino acids of animal-sourced proteins more closely match the profile of essential amino acids required by humans. To achieve the same intake of essential amino acids from plant-based foods, requires a combination of cereals and legumes found in all cultures. Examples include rice and beans in Africa, tortilla and beans in Mexico, and rice and dhal in Asia.

Phytochemicals

These are bioactive non-nutritive plant compounds including carotenoids, alkaloids, nitrogen containing compounds and organosulphur compounds that are present in fruits, vegetables, grains and other plant foods. Evidence for the efficacy of these phytochemicals in promoting health (or preventing disease) is patchy and often anecdotal, but it strongly points to health benefits conferred by consuming a diverse range of whole plant-based foods, rather than taking plant-derived supplements or extracts (Rui, 2004).

Vitamins

Consumption of a range of green leafy vegetables together with red, orange and yellow fruits and vegetables all contribute to vitamin A consumption via β- carotene. The absorption of β-carotenes and vitamin A are enhanced by the presence of small amounts of fat or oil in the diet – achieved through the consumption of oilseeds, oily fruits and nuts.

Minerals

Humans require at least 18 essential minerals many of which come primarily from plant sources. Deficiencies of zinc, calcium, and selenium are evident in regions where either the diet is monotonous or based on a limited range of foods from mineral poor soils.

Diversification of the diet, through the consumption of a range of species, can provide the essential nutrients required for optimal health.

Anti-nutritional factors

Besides these beneficial components, plants may also contain compounds that are detrimental (and occasionally toxic) to health. These include:

Digestibility inhibitors

The presence of chelators such as phytates and oxalates in the diet, primarily from green leafy vegetables, can reduce the bioavailability of minerals including calcium, iron and zinc (Gibson et al., 2010). Furthermore, protease inhibitors such as tannins and trypsin inhibitors, commonly present in the seed coats of grains, legumes and seeds reduce the digestibility of proteins.

Toxins

These include alkaloids, cyanogens, goitrogens, carcinogens, haemagglutinins, protease inhibitors (tannins, trypsin inhibitor, phenolic compounds) amongst others. Cyanogenic and other toxic compounds are present in many foods, making them dangerous to consume without proper processing. Simple household processing techniques including soaking, heating, roasting, germination and fermentation are used to denature or destroy anti-nutritional compounds such as cyanogens, protease inhibitors and phytates (Gibson et al., 2000).

The need for research on the nutritional potential of underutilised species

There is a compelling need to research currently underutilised plants to determine what they contain and how the benefits can be delivered while minimising any deleterious contents. Moreover, very little is known about the effects of agronomic practice, (from planting, through growth, fertilizer application, irrigation, harvest) processing and storage on the accumulation (and potential disappearance or sequestration) of minerals and their bioavailablility. This knowledge is essential if the full benefits from a more diversified, plant-based diet are to be gained. There are systematic general differences between plant families in the mineral nutrients that they contain (White et al., 2012). For example, the seeds of most cereals have lower concentrations of zinc and iron than seeds of legumes (Gregory et al., 2017).

Also, because of differences in the way nutrients are transported inside the plant, tissues such as tubers, fruits and seeds are frequently poorer sources of zinc and iron than the leaves. Leafy vegetables are particularly rich sources of many mineral nutrients.

However, the concentration in plant tissues is also considerably affected by the environment in which the plant is growing.

Specific plants contain specific nutrients which may benefit human diets, especially if the diet is diversified by the inclusion of one or more of these lesser known species. Here we detail the benefits of five crops that are consumed by some populations, but could provide wider benefits if they were cultivated more widely.

The five species are chosen as exemplar crops that are currently the focus of individual and scattered research programmes. They were selected to illustrate both the potential contribution that underutilised species could make in addressing global hunger and nutritional security, whilst at the same time highlighting the gaps in our knowledge of the true potential of these and other species.

Effort is urgently needed to substantially improve the quality and quantity of dietary data.

GLOPAN Foresight Report (2016)

Moringa *(Moringa oleifera)*

Moringa is a fast-growing, drought resistant tree, native to the Himalayas, but cultivated throughout the world, especially in the dry and lowland tropics, including in Africa, Asia, Latin America and the Caribbean (Thurber and Fahey, 2009; Olson et al., 2016). The tree is primarily grown for its nutrient rich leaves and pods, although it does have other uses, including for shelter and fence building, firewood, animal feeding and medical application. It is often referred to as the 'miracle tree' for its numerous reported health and nutritional benefits. The leaves are reported to be a good source of micro and macro-nutrients, especially of vitamins A, B and C, and several minerals including calcium, potassium, magnesium, iron and zinc (Aslam et al., 2005, Thurber and Fahey, 2009; Olson et al., 2016). They also contain significant levels of essential amino acids. Much of the data on the role of moringa in treating skin diseases, respiratory illnesses, cancer, hypertension, diabetes and more, is still anecdotal and requires coordinated clinical trials to ascertain its effectiveness.

Moringa is a diverse genus, encompassing a range of different species suited to different climates and agro-ecological zones.

Despite its nutritious reputation, there has been very little in the way of systematic identification of the variation in nutrient profile of the leaves across the genus and under different agronomic production systems. Studies of dried moringa leaves report protein values from 19 to 35 g/100g; similarly calcium and potassium concentrations vary two to three fold (Aslam et al., 2005; Olson et al., 2016).

Moringa leaves can add quality and nutritional value to diets, simply by adding the leaves to starchy staple diets. This simple food-based approach to improved nutrition, has multiple benefits to the community, not only in terms of improved nutrition, but as a sustainable approach to community development. It is preferable to improved nutrition via international feeding centres and food supplement programmes since it provides the community with other livelihood options. These alternatives are also effective at reducing micronutrient deficiency diseases, but lack the additional benefits to the community. The food based approach gives communities control over their nutrition and provides opportunity for income generation through small scale production, processing and sale of the products (Thurber and Fahey, 2005).

Bambara groundnut *(Vigna subterranea)*

Bambara groundnut (*Vigna subterranea*) is a drought tolerant legume that is native to west Africa, but cultivated in pockets in Indonesia, Thailand, Malaysia and India. It is the third most important grain legume in semi-arid Africa, but still remains largely neglected and under-utilised. Traditionally known as a woman's or poor man's crop, it is remarkable in that it can yield on poor soils when other crops fail. Bambara groundnut is still a landrace with huge genetic variability depending on the country of origin. Its closest relative is the black-eyed bean (*Vigna unguiculata*). A consolidated period of research on this crop over the last two decades by researchers at the University of Nottingham, in collaboration with African and European Union (EU) partners, has delivered significant findings on the genetic habit and traits of this plant, in particular its need for a specific photoperiod in order to fruit. In terms of nutrition, bambara groundnut or Jugo bean, as it is referred to locally in Swahili, is known as the food that satisfies. It contains up to 60% carbohydrate, 16-20% protein and low levels of oil (up to 6-8%) that match the recommended nutrient intake profile for optimum health (Brough and Azam Ali, 1992).

It is also reported to be a rich source of minerals and essential amino acids (Yao et al., 2015). Simple methods such as soaking, dehulling, boiling and sprouting can be used to significantly decrease levels of phytic acid in the seeds, while at the same time, sprouting may enhance the protein level (Igbedioh et al., 1994).

Bambara groundnut seeds are grounded into flour and used to partially replace other cereals (wheat) in breads and baked goods. The fresh seeds can be ground and homogenized to produce a vegetable milk, which can be further processed into products such as a protein rich cheese, tofu like product or yogurt (Poulter and Caygill, 1980). Combined with maize flour, bambara groundnut has been used to improve the nutritional quality of traditional African weaning foods (Mbatal et al., 2009).

Amaranth *(Amaranthus)*

Amaranth is a genus of annual or perennial plants, consisting of about 60 species that are grown for human consumption, either as a grain or leafy vegetable. The genus originated in Central America where it was an important food for the Aztec, Mayan and Incan civilisations. Scientists have been aware of the potential of this species since the 1970s when it was selected as one of the world's most promising crops and identified as a major potential crop by the National Academy of Sciences (1985). It is now attracting renewed research interest, mainly due to the high nutritional value of the seeds, resistance to drought and ability to produce grains in a relatively short time. Thus, it is seen as an important crop for ensuring nutritional security in the climates of the future.

Compared to other cereal grains, amaranth is reported to contain the highest amount of protein, twice the content of essential amino acid lysine, more dietary fibre and between 5 and 20 times as much iron and calcium (Venskutonis and Kraujalis, 2013).

Amaranth grain is valued for its lipid content, which is primarily composed of triacylglycerols, phospholipids, squalene and lipid soluble vitamins. Values for lipid concentration range from 4.8 to 19.3% depending on species, location and method of lipid extraction. The content of all components varies widely between cultivars and species and to some extent is modifiable by agronomic practice such as fertiliser and water application. Amaranth oil is highly unsaturated, so is prone to changes during heating and processing (Venskutonis and Kraujalis, 2013).

Amaranth protein is considered to be a good source of most essential amino acids, in particular lysine and tryptophan, although there is some inter-cultivar variability. Some reports indicate that cooking increases the nutritional value of the grain, suggesting either the presence of heat sensitive anti-nutritional factors in the grain or that cooking somehow increases the availability of proteins in the grain. Sprouting is another process that has been used to enhance the nutritional value of the grain by increasing the levels of antioxidants in the form of anthocyanins and total phenolics (Pasko et al., 2009).

Proso millet *(Panicum miliaceum (L))*

Proso millet is one of the oldest cereals consumed by humans. It is drought tolerant and grown by subsistence farmers on marginal lands in African and Asian countries. Millets are particularly valuable in semiarid regions because of their short growing seasons. Proso millet is less widely grown than foxtail, finger and pearl millets. It is grown for human food, for bird seed and for use in feeding rations. In the USA, it has been found to be particularly useful for inclusion in crop rotation systems for the control of weeds (Lorenz et al., 1980). Proso millet is considered to be a good source of protein, dietary fibre and many micro-nutrients, in particular calcium, although the high levels of phytate may limit the bioavailability of micronutrients.

The concentration of protein in proso millet is equivalent to that in wheat (about 11-12g/100g DM), but its quality in some varieties is superior to the protein in wheat, thanks to the high levels of essential amino acids. Both Ravindran (1991) and Kalinova and Moudry (2006) highlight varietal differences in protein content and effects of drought on both quality and quantity of protein in proso millet seeds. Park et al., (2008) and Nishizawe et al., (1990; 1996) indicated that the protein in proso millet may be beneficial in altering the levels of plasma glucose, insulin and high density lipoprotein (HDL) cholesterol, factors that are significant in the development of type II diabetes and cardio vascular diseases linked to cholesterol metabolism.

Proso millet flour has the potential to replace wheat flour in some baked goods at inclusion levels up to 30%. Because it lacks the protein gluten, it is unable to completely replace what flour in traditional baked and leavened products, but has the potential to be a nutritious cereal for individuals who are gluten intolerant.

Winged bean (*Psophocarpus tetragonolobus*)

Winged bean, also known as four-angled bean, is a tropical legume, believed to originate in Papua New Guinea and grown predominantly in South East Asia and parts of Africa. It is a perennial climbing plant, characterised by its tuberous roots and winged or angled pods (Nwokolo, 1996). The plant is unique in that the seeds, tubers, leaves and pods are all edible and are rich sources of protein (Reddy, 2015). The tubers are reported to contain about 20% protein, which is more than 12 times that found in a potato. The roasted seeds are used as a coffee substitute and the pale blue flowers to add colour to foods (Reddy, 2015). Despite being a perennial, it is usually grown as an annual plant for the nutritious pods. The seeds of the legume are reported to have a high protein content (30-37%), but also contain significant levels of anti-nutritional factors, mainly trypsin inhibitor, haemagglutinin, tannins and phytic acid, which reduce the nutritional value.

The seeds are a rich source of oil (up to 17%), vitamin E and calcium (Reddy, 2015). Raw winged bean seeds are toxic to rats. Heat treatments can be used to deactivate the protease inhibitors and toxins and improve the overall nutritional value (Kadam., 1987). Several researchers have successfully incorporated cooked winged bean seeds into fish diets as a replacement for fish meal (Fagbenro, 1999).

One notable feature of the descriptions of these five species and of currently underutilised crops in general, is the partial detail that exists regarding their nutritional benefits. Rarely is a full description of carbohydrates, proteins, fats, minerals, vitamins, amino acids, phytochemicals and anti-nutritional factors available to ascertain the full benefits relative to other plants. This reflects a lack of investment in research and has led to advocacy for particular ‘miracle’ or ‘super’ plants rather than evidence-based assessments of potential.

As highlighted in the GLOPAN 2016 Foresight Report, effort is urgently needed to substantially improve the quality and quality of dietary data. We require policies that build on the initiatives of FAO and the WHO to develop the Global Dietary Database (GDD) and the Global Individual Food consumption data Tool (GIFT) (GLOPAN 2016).

Recommendations to policymakers

Preamble

Drawing together all these key issues, it is clear that providing food and nutritional security for an estimated 8.5 billion people by 2030 in an increasingly hot and riskier world can no longer rely solely on the three major cereal staples. At present, over 50% of all plant-based food consumed globally is based on these three crops – which generally fail to perform in harsh environments, but, additionally, even when biofortified, cannot provide all the micro- and macro-nutrients essential to overcome malnutrition. There is therefore a very compelling case for complementing these staples by drawing on the vast diversity of underutilised crops that include species adapted to all environments including the harshest.

Attention should be shifted towards policies and food systems that support the quality of food as well as its quantity. This is as important in developed countries where diseases of over-consumption (of calories) occur as it is in countries where under-nutrition and hunger continue to be serious threats to economic development. Agriculture and nutrition policies should also consider the rural to urban shift, and the need to provide quality diets in urban and peri-urban areas. Increased consumption of underutilised plants is one potential solution that addresses this shift in focus.

Collectively, this requires that the following policy issues need to be addressed:

General

There is already compelling evidence to suggest that diets that include diverse fruits, vegetables, nuts and berries in addition to cereals and other staples are essential for human health. Policies are, therefore, required to ensure that this diversity is effectively exploited for the benefit of all – particularly the rural and urban poor. Opportunities for improving livelihoods through income generation for these crops are also very significant.

Infrastructure

Investment in infrastructure across the food system is required to support the production, processing and marketing of underutilised crops. Small-scale, peri-urban and subsistence farmers require encouragement to produce more of these species and to use them to partially replace or complement cereals and animal-based foods.

Research

Much of the literature on the potential health benefits of consuming (as yet) underutilised plant foods is anecdotal rather than evidence based. To provide a credible evidence base requires a concerted research effort and investment in these neglected species.

Key research needs include:

A concerted research effort to examine and analyse the proximate composition of crops/plants/species produced under a range of agro-climatic conditions. This will also need to include varietal differences, and the impacts of processing and storage on nutritional value.

Whilst biofortification of major cereal crops and other staples has a major role to play in alleviating some micronutrient deficiency diseases, and is currently receiving very significant investment, it is not the only option available to improve nutritional security. In addition to macro- and micro-nutrients, plants contain a myriad of non-nutrient phytochemicals that have been linked with the prevention of a number of chronic diseases.

Consumption of a diverse range of whole plant foods, rather than the extracted phytochemicals, can provide a range of additional nutritional benefits. These links between plant-based diets and reduced incidence of cancer and cardiovascular diseases require further investigation.

Capacity building

For underutilised species to play a more significant role in dietary diversification and nutritional security, it is essential to include capacity building for all stakeholders involved in the value chains. This includes farmer associations, other private sector players including the seed industry, national government and non-government research and advisory bodies, extension workers, health workers and the general public who will be the consumers of the diversified diets.

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Crops For the Future
Jalan Broga, 43500 Semenyih
Selangor Darul Ehsan, Malaysia

T : +6 (03) 8725 2800
E : enquiries@cffresearch.org

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