Food and Agriculture Organization of the United Nations
World Health Organization
ICN2 Second International Conference on Nutrition
better nutrition better lives

Linking Nutrition and Agrobiodiversity

Gudrun B. Keding, Bruce Cogill

Gudrun B. Keding

Bioversity International, Nutrition and Marketing of Diversity Programme, Nairobi, Kenya
g.keding@cgiar.org

Gudrun Keding is a Postdoc research fellow at Bioversity International, Regional Office for Sub-Sahara Africa, Nairobi, Kenya and working in the Nutrition and Marketing of Diversity Programme. She holds a B.Sc. and M.Sc. in Agriculture from Georg-August-University Goettingen, Germany and a Ph.D. in Agriculture with a focus on international nutrition from Justus-Liebig-University Giessen, Germany. After working with the World Vegetable Center in Tanzania within a project on "Promoting Indigenous Vegetables for Nutritional Health in Eastern and Southern Africa" for her PhD research, she is currently leading a project on "Improving Nutrition through Local Agrobiodiversity (INULA)" in Kenya which aims to improve the nutritional health of women and children under two years through increased utilization of local agricultural biodiversity. Research is being undertaken in close collaboration with different Universities and should contribute to a better understanding of the role that agricultural biodiversity plays for dietary diversity and quality as well as nutrition and health in general.

Bruce Cogill

Bioversity International, Nutrition and Marketing of Diversity Programme, Rome, Italy
b.cogill@cgiar.org

Bruce Cogill is the program leader for Nutrition and Marketing of Diversity at the Rome head office of Bioversity International. He has an extensive experience in management, food and nutrition policy, nutrition, agriculture and environment, research, programs and practice. He holds a Ph.D. and Master's degrees from Cornell University in the U.S.A. where he studied International Nutrition and Agricultural Economics and an undergraduate degree from Australia in Food Science and Technology. He has consulted on food and nutrition for Universities, the UN, the World Bank and others. His experience includes appointments as the Chief of Nutrition at USAID Washington where he championed the nutrition effort for the Feed the Future and the Global Health Initiative. He was coordinator for the Global Nutrition Cluster at UNICEF where he coordinated over 37 NGOs, academic, UN and technical agencies in the food and nutrition preparedness and response to emergencies. In addition, he spearheaded the successful FANTA and A2Z projects and USAID's efforts in research and programming for nutrition and food security, HIV, micronutrients and in the community management of severe and moderate acute malnutrition. He has contributed to strategy developments for large donors and served on technical committees and recently was on the Board of the Micronutrient Initiative, GAIN Alliance, and the Chair of the Steering Committee for the Health and Nutrition Tracking Service at WHO. He has lived and worked in several countries including Mozambique, Kenya, and Papua New Guinea. He has published extensively ranging from practical guides and reviews to articles in peer reviewed journals including one of the most popular guides on anthropometry. He has lectured and worked at various universities including Columbia, Johns Hopkins, Tulane, Queensland, Roma Tre, Oxford and others. He has appeared on television news programs and in print as an authority on international nutrition and sustainable diets.

Abstract

It is already known that a lack of diversity is a crucial issue, particularly in the developing world where diets consist of starchy staples to a great extent with less nutrient-rich foods such as animal source food, fruits and vegetables being available, accessible or known to be important for a balanced diet. At the same time it is acknowledged that the consumption of a variety of foods across and within food groups almost guarantees adequate intake of essential nutrients and important non-nutrient factors. Still, it is not well understood how agricultural systems and the benefits derived from agrobiodiversity affect nutritional quality, consumption patterns, and nutrition and health status, in particular of people in the developing world. A study in Tanzania showed that a direct link between production and consumption of cultivated traditional vegetables exists; however, this link did not exist for exotic vegetables, usually bought from markets, and also not for wild vegetables which highlights the importance of taking the sources of foods into consideration. Among study participants in Tanzania the amount of vegetables consumed decreased with increasing diversity in the diet suggesting that other food groups, being less nutritious such as beverages and sugar, increased the dietary diversity and replaced partly the vegetables in the diet. Consequently, different forms of an increase in dietary diversity must be distinguished and next to reviewing dietary diversity scores for measuring dietary adequacy further determinants of sustainable diets, namely cultural acceptability, accessibility and environmental sustainability, should be considered when linking nutrition and agriculture.

Summary

While the causes of malnutrition are complex, a leading cause is suggested to be a general simplification of diets with a decline in diversity and nutritional quality. The change in agricultural production from more varied cropping systems to more monoculture cereal systems seems to be contributing to micronutrient deficiencies by limiting food-crop diversity (Welch 2008). Already more than one decade ago the gap between agriculture and nutrition was observed with 'Hidden Hunger' being partly due to agriculture not having nutrient output as an explicit goal on the agenda; and nutrition and health communities having never considered using agriculture as a primary tool in their nutrition programmes.

A study in Tanzania undertaken by the World Vegetable Center and partners in 2006/2007 revealed that a direct link between production and consumption of cultivated traditional vegetables exists. However, no association was detected between production and consumption of exotic vegetables, as many of them were bought from markets, and also no relation to consumption was found for vegetables collected from the wild (Keding 2010). This highlights the importance of taking the sources of foods into consideration which are next to own production the collection from the wild, buying from markets, receiving foods as gifts, exchange of foods and food aid. In the same study in Tanzania, dietary diversity scores (DDS) of women were significantly associated with the number of vegetables that women cultivated/collected. In addition, those women who cultivated/collected vegetables more consistently (similar species richness year round), but also those who sold their products, had higher DDS (Keding et al 2012). Consequently, not only the availability of agricultural diversity was linked to dietary diversity, but also the possibility of marketing agricultural products which would contribute to cash income that in turn can be spend on additional foods. In fact, the relationship between household food production and nutrition of household members is not straightforward, yet, rather complex involving selling and purchasing of foods, control of income, social biases (Girard et al 2012) as well as decision making processes.

In the Tanzanian study, vegetables were among those food groups consumed by nearly every participant year round; however, the amount of vegetables consumed decreased with increasing diversity in the diet. Obviously, less healthy and valuable food groups such as beverages and sugar accounted for a high dietary diversity and replaced the amount consumed of more healthy food groups such as vegetables (Keding et al 2012). Consequently, different forms of an increase in dietary diversity must be distinguished and dietary diversity scores should be either enhanced with a measure of dietary quality or used in combination with further measures of dietary quality and food quantity.

In general, holistic food-based system approaches and a focus on linking agricultural production to improving human health, livelihood and wellbeing (Welch and Graham 1999),

thus, nutrition-enhancing food and agriculture systems, should be given more attention. Instead of supplementation strategies, food-based strategies using the locally available agricultural biodiversity (ABD) but also wild/collected food diversity and promoting consumption of a wide range of foods across nutritionally distinct food groups may be more cost-effective and sustainable on a long-term basis. Such food-based approaches would also benefit not only single household members but the whole household or even community that might be suffering from the triple burden of nutrition. Especially through a focus on fruits and vegetables, pulses, nuts and seeds and to a certain extend animal source foods both under- and overnutrition can and should be addressed in one approach. This could be a multiple-crop or multiple-food approach through which multiple contributions, e.g. not only targeting the deficiency of one nutrient but malnutrition in general, can be accomplished.

It is already known that a lack of diversity is a crucial issue, particularly in the developing world where diets consist of starchy staples to a great extent with less nutrient-rich foods such as animal source food, fruits and vegetables being available, accessible or known to be important for a balanced diet. At the same time it is acknowledged that the consumption of a variety of foods across and within food groups almost guarantees adequate intake of essential nutrients and important non-nutrient factors (Bioversity 2011). While several research studies have already well documented the links between dietary diversity and diet quality and nutritional status of children (Arimond and Ruel 2004; Kennedy et al. 2007; Rah et al. 2010; Savy et al. 2008), as well as associations between dietary diversity, food security and socioeconomic status (Hoddinott and Yohannes 2002; Ruel 2003; Thorne-Lyman et al. 2009) it is now crucial to understand how agricultural systems and the benefits derived from ABD affect nutritional quality, consumption patterns, and nutrition and health status, in particular of people in the developing world. Thereby, the concept of sustainable diets should be applied and the relationship between the multidimensional determinants of environmental sustainability, accessibility, cultural acceptability and nutritional adequacy needs to be examined. Moreover, a key element that needs to be understood is how to promote diversity to improve the efficiency and sustainability of food systems while at the same time alleviating the negative impacts of the dietary transition (Fanzo et al. 2012). When working along the food chain a systemic approach needs to be applied with the food chain integrating next to environmental issues, such as soil, water and health hazards, also intersectoral communication, knowledge production and education.

Keywords: agrobiodiversity, dietary diversity, Tanzania, nutrition, sustainable diets, vegetables

1. Background: The “agriculture - nutrition gap”

Agriculture-health interactions are complex and can be direct or indirect, namely direct consequences of present food consumption patterns and agricultural production practices on human health; and indirect effects on health of various issues relating to agricultural development and sustainability (Waage et al. 2011). The “agriculture – nutrition gap” is partly due to agriculture not having nutrient output as an explicit goal on the agenda; and nutrition and health communities having never considered using agriculture as a primary tool in their nutrition programmes (Welch and Graham 1999). To maximise the nutrient output of farming systems has unfortunately never been an objective of agriculture but rather to maximise production while minimising costs. The change in agricultural production from more varied cropping systems to more monoculture cereal systems seems to be contributing to micronutrient deficiencies by limiting food-crop diversity (Welch 2008).

The agriculture, health and nutrition sectors are not only separated at university-level training and research but also at development organization and governmental ministry level. It is suggested to integrate health and nutrition goals clearly into the design and implementation of agricultural projects in order to have a larger health and nutritional impact (Pinstrup-Anderson 2012). Consequently, agriculture with its multifunctional character needs to accommodate for the different factors that constitute the concept of sustainable diets (as defined by FAO and Bioversity 2012) in order to be nutrition-enhancing.

It is argued that homestead food production, e.g. in home gardens, can have a direct and positive impact on dietary diversity and, consequently, the dietary quality of household members (Iannotti et al. 2009; Olney et al. 2009). However, only recently a first international conference has highlighted the importance of leveraging agriculture for improving nutrition and health, suggesting that so far there is little concrete evidence on how agriculture-nutrition linkages work (IFPRI 2011). The present study investigates associations between human nutrition and agriculture focusing besides others on an example of linking nutrition and vegetable production/collection in Tanzania.

To investigate the links between nutrition and agriculture a systemic approach needs to be applied with the food chain integrating next to environmental issues, such as soil, water and health hazards, also intersectoral communication, knowledge production and education (Figure 1). The present study will mainly focus on the production side of the value chain and how a greater diversity in the farming system, which could positively contribute to soil health, water holding capacity or other ecosystem services, would be related to nutritional outcomes.

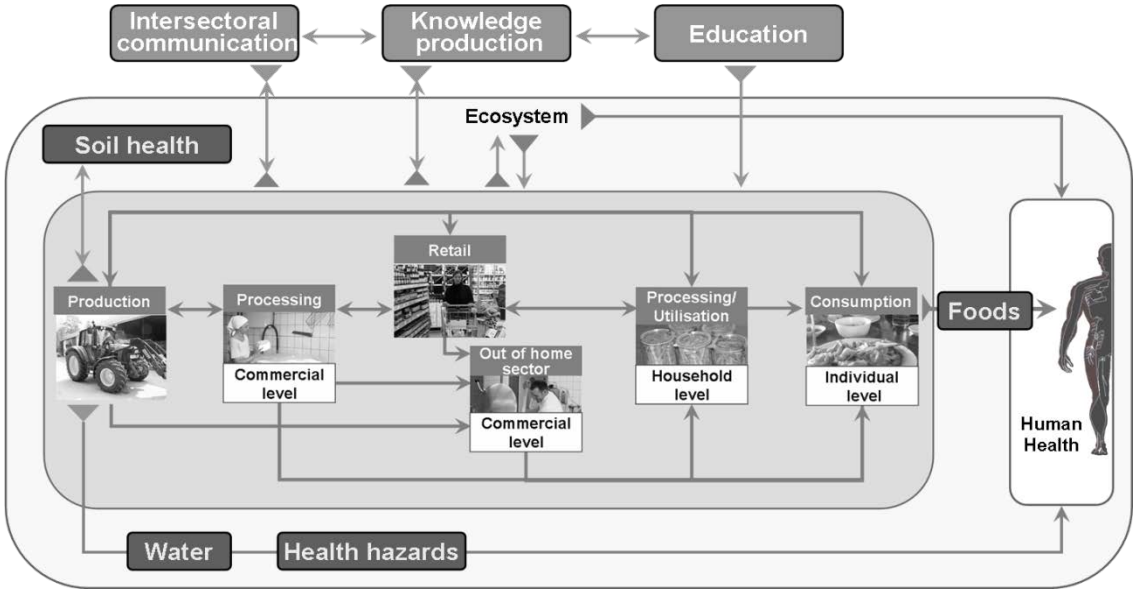

Figure 1: The food chain and recommended entry points for promotion of nutrition-sensitive agriculture (Keding et al.) modified after (Schneider and Hoffmann 2011)

2. Bridging the gap: food based approaches

Already more than one decade ago it was suggested to link agricultural production to improving human health, livelihood and wellbeing and to focus on holistic food-based system approaches (Welch and Graham 1999). Food-based approaches which include food production, dietary diversification and food fortification, are sustainable strategies for improving the quality of the diet and for overcoming and preventing malnutrition. Increasing access to and availability and consumption of a wide variety of foods across nutritionally distinct food groups not only have a positive effect on micronutrient status but also contribute to improved nutrition in general. In addition to its importance for nutrition, food has social and economic values. Along the entire food chain critical points should be identified where the nutritional quality is reduced or at risk and measures for safeguarding this quality need to be applied (FAO 2011).

Food-based approaches would also benefit not only single household members but the whole household or even community that might be suffering from different types of malnourishment or even the triple burden of malnutrition. A great number of food-based interventions still aim at the alleviation of a single nutrient deficiency. Yet, with the knowledge of synergies in the physiologic functions of nutrients being available, interventions need to focus explicitly on improving overall diet quality and it is, for example, suggested to mobilise ‘agricultural biodiversity to ensure dietary diversity’ (Frison et al. 2006). Therefore, a multiple-crop or multiple-food approach instead of a single-crop focus shall be applied. Through this also a multiple-output and multiple contributions (e.g. not only

to combat Vitamin A deficiency but different types of malnutrition, e.g. non-communicable diseases (NCDs)) can be accomplished.

2.1. Local agrobiodiversity: how to assess its contribution to local diets?

Agrobiodiversity can provide a rich source of nutrients for adequate dietary diversity and quality, a safety net against hunger, and a basis for strengthening local food systems and environmental sustainability. Still, some important questions are yet to be answered, e.g. how on-farm agrobiodiversity contribute to household food consumption, dietary diversity and quality; how agrobiodiversity can be linked to improved nutrition and health outcomes and benefits; and how agrobiodiversity can be scaled for commercial use while maintaining biodiversity and ecosystems and improving human health. Agriculture approaches planned with nutrition in mind, thus, nutrition-enhancing agriculture, should start with considering and understanding further the role of agrobiodiversity in improving dietary quality and dietary diversity, i.e. to consume of a wide variety of foods across nutritionally distinct food groups (Bioversity 2011). Also, next to agriculture or on-farm biodiversity, the diversity of foods collected from the wild as well as market food diversity needs to be taken into account and their contribution in relation to on-farm products be assessed, especially considering seasonality and prices.

When the nutrient contents and prices of foods locally available are known this can be done using linear programming to identify a nutritionally adequate diet of the lowest costs, for example, for a child of a specific age. The assumption thereby is that price and nutrient contents are linearly related to food weight (Briend et al. 2001). As the availability of foods providing specific nutrients as well as their prices vary between seasons it is necessary to do the calculations for different months in order to come up with matching recipes. Next to seasonality also the issue of foods collected from the wild or fallow lands, for which costs and nutrient content are difficult to assess, needs to be taken into consideration.

Wild as well as neglected and underutilized foods can be added to the meals to achieve nutritionally adequate diets. Further, it can be calculated whether a cost reduction of a nutritionally adequate diet can be achieved by replacing more costly foods with wild and underutilized species (Bioversity International et al. 2013). Adequate intake of all nutrients might, however, not be possible for all population groups as was shown in a study in Kenya. When adding five selected wild fruit and vegetable species to the diet of children 12 to 24 month it was possible to reduce the cost of the diet up to 64% in the dry season and still meet the recommended intakes for iron. However, for 6 to 11 month old infants intakes of iron were still inadequate when adding the five wild foods to the diet (Termote et al. 2013).

When the type and amount of nutrients produced in each food system has been identified, an optimisation model can analyse which cropping strategies might improve the nutritional quality of people using existing resources. When this model was applied to compare different cropping systems in Ethiopia, the results suggested expanding the land area under more nutritious and varied crops such as beans, kales and enset at the cost of the staple crops barley, maize and sweet potato. A shift from a cereal/root crop dominated system to a perennial-enset dominated system would in addition decrease soil erosion. (Amede et al. 2004)

Also, an interdisciplinary approach linking agriculture and ecology to human nutrition and health, also described as “econutrition”, can be applied as obviously these disciplines share common concerns such as loss of biodiversity, decline in soil fertility, decrease in food production and increase in malnutrition (Deckelbaum et al. 2006). The concept of functional nutritional diversity emphasises on the availability of nutritionally distinct crops in a cropping system in order to address nutrition security issues. In general, the capacity of a farm to deliver a wide range of nutrition functions to its owners increases with increasing farm agrobiodiversity. However, a farm with many species could have low nutritional diversity and *vice versa*. (DeClerck et al. 2011) Here it is important to differentiate between inter- and intra-species diversity as for example a great diversity of beans can be important for culinary and cultural issues and can increase farmers’ resilience to climate change but might not contribute to nutritional diversity in terms of nutrient uptake.

2.2. Dietary diversity and seasonality: how to achieve an adequate diet during all seasons?

It is already known that a lack of diversity is a crucial issue, particularly in the developing world where diets consist of starchy staples to a great extent with less nutrient-rich foods such as animal source food, fruits and vegetables being available, accessible or known to be important for a balanced diet. At the same time it is acknowledged that the consumption of a variety of foods across and within food groups almost guarantees adequate intake of essential nutrients and important non-nutrient factors. (Bioversity 2011)

The links between dietary diversity and diet quality and nutritional status of children have been already well documented (Arimond and Ruel 2004; Kennedy et al. 2007; Rah et al. 2010; Savy et al. 2008) as well as the associations between dietary diversity, food security and socioeconomic status (Hoddinott and Yohannes 2002; Ruel 2003; Thorne-Lyman et al. 2009). Now, it is crucial to understand how agricultural systems and the benefits derived from ABD and wild foods affect nutritional quality, consumption patterns, and nutrition and health status, in particular of people in the developing world. Thereby, the quality and type of

foods within one food group might be more important than dietary diversity alone as shown in the example of the vegetable project below (chapter 3.2).

Year-round food security is important meaning a consistent availability and accessibility during all seasons (UN 2012). Though, seasonal food shortage is seemingly a short-term problem it has also lasting effects and households may become trapped in a cycle of poverty (Hadley et al. 2007). Buffering capacities are needed for affected households and again agriculture can enhance nutrition security through providing foods more equally throughout the year. Here, agricultural production alone cannot take responsibility but different stakeholders along the value chain, especially in food processing, need to be considered.

To fill the nutritional gaps during certain seasons and compensate food shortages not necessarily the same foods need to be available year-round but foods with similar quality and similar nutrient-content that can substitute each other. For agriculture to be nutrition-enhancing this requires provision of foods according to nutritional needs of a population. A sophisticated cropping schedule including diversification of farm crops in order to distribute planting and harvesting more evenly across the year could not only increase food availability but also ease women's agricultural workload which has been identified as an important barrier for improving nutrition behaviour in the Bolivian Andes (Jones et al. 2012). This is especially important when food preservation is required directly after harvest but cannot be done due to too much work during harvest seasons.

To bridge the gap in availability of fresh foods processing of foods is a necessity and can also help minimizing food losses. Next to time constraints of women mainly responsible for food processing at household level, most sophisticated, time saving technologies are not applicable in the absence of electricity as it is prevalent in many rural areas of developing countries. Traditional technologies, however, such as the drying of food in direct sunlight in front of the house or at road sides, lead to high losses in food quantity and quality (Ibeanu et al. 2010). Collaboration between farmers, manufacturers and food scientists is therefore needed to improve access to appropriate technologies for the locally grown foods.

While not in every agricultural system all nutritionally distinct foods can be produced at all times, next to food processing nutrition education is fundamental which needs to work with the foods available during different seasons and include others from further sources such as the wild and markets. Also, agriculture extension services need to include nutrition education among food producers to ensure that the portfolio of foods is being diversified and if possible all necessary foods from a nutritional point of view are produced.

Although, for example, the integration of legumes would create a win-win situation for both agriculture and nutrition, many studies still focus only on the contribution of legumes to soil

nutrition and health and the general positive effects on crop productivity, however, not to human nutrition and health (Cakmak 2002). Still, the example of a study on legume diversification for improved human nutrition and soil fertility in Malawi shows that participants testing legumes on their farms reported feeding significantly more edible legumes to their children as compared to control households (Bezner Kerr et al. 2007). This study involved multi-educational activities and participatory research through which farmers besides others acquired knowledge of the contribution of legumes to both child nutrition and soil productivity. Awareness creation through nutrition education including also hygiene and health topics needs to go hand in hand with agricultural production.

3. Case study: Vegetable production and consumption in Tanzania

This repeated cross-sectional study in Tanzania, led by the World Vegetable Center AVRDC, included three surveys during different seasons within a whole year, namely the dry season during June/July 2006, the short rainy season during November/December 2006 and the end of the dry and beginning of the long rainy season during March/ April 2007. Three research districts were chosen in order to have significant differences in a variety of factors such as climate, altitude, ethnic groups and distance to urban centres. Women to participate in the study were randomly selected in each of the 18 villages (6 per district, a selection of those already visited within a baseline survey of a preceding AVRDC project) by the responsible village extension officer and on the basis of household lists. Selection criteria included reproductive age (i.e. age between 15 and 45 years) and cultivation of vegetables. The study focused on women only as they are usually responsible for food preparation and vegetable cropping and they are also a vulnerable group in terms of nutritional health (Keding et al. 2007; Lyimo et al. 2003; Price 2003). From originally 360 participants at the start of the project only 252 women attended all three meetings and consequently formed the study cohort. The most common reasons for dropping out were illness, travel, relocation or workload.

Each survey comprised an individual interview, which included a semi-quantitative 24-h recall of food consumption (single food items and quantities) and a food frequency questionnaire over the past week for vegetables only. It further contained questions on the socio-economic status of participants (during the first survey only) and on vegetable production during the time of interview. The 24-h recall was chosen i.a. because the method had already been successfully applied to dietary diversity score (DDS) calculation in an African study (Savy et al. 2007).

3.1. Linking vegetable production and consumption: Does diversity in the field equal diversity on the plate?

In the present study, a direct link between production and consumption of cultivated traditional vegetables was found, however, no association was detected between production and consumption of exotic vegetables as many of them were bought from markets. Also no relation to consumption was found for vegetables collected from the wild (Keding 2010). This highlights again the importance of taking the sources of foods into consideration which are next to own production the collection from the wild, buying from markets, receiving foods as gifts, exchange of foods and food aid – and not only focus on on-farm agrobiodiversity.

The total number of different vegetable types consumed by study participants was substantially lower than that of vegetable types produced. In some cases, even more than double the number of vegetables was named to be cultivated/collected than consumed. One reason for this could be that it was asked for vegetables cultivated or collected “right now” in the garden/field, while participants only recalled the consumption of vegetables within the last week. However, it was striking that especially the number of vegetable types collected from the wild was much greater than the one consumed, while the number of vegetable types cultivated and consumed was rather similar. Obviously, vegetables collected from the wild were of much less importance for consumption, they were not consumed regularly (here weekly) and also in smaller quantities.

This study further showed that exotic vegetables were obviously seldom cropped by study participants, yet, they were relatively much more consumed in comparison to traditional vegetables. Data on the sources of vegetables confirmed that most exotic vegetables consumed by participants were bought, namely, on average, 95% of onions, 94% of white cabbage, 86% of tomatoes and 57% of Chinese cabbage which explains the discrepancy between production and consumption.

Interestingly, women in a humid coastal district with the highest vegetable diversity available consumed the lowest amount of vegetables. In contrast, women in two semi-arid inland districts, with lower vegetable diversity available, consumed greater quantities. Apparently, high agrobiodiversity alone does not account for high consumption quantity of this diversity. While some authors state that the decreasing use of traditional vegetables is due to decreasing availability (Adedoyin and Taylor 2000; Okeno et al. 2003), others argue that traditional vegetables are quite available especially during the rainy season, e.g., in Nigeria, but are among the least consumed foods (Maziya-Dixon et al. 2004). This might be due to their perception (e.g. as ‘poor man’s crop’) and as mentioned in the previous chapter awareness creation through nutrition education needs to accompany promoting, for example, the production of certain vegetables.

Traditional vegetables were consumed more often and also in a larger quantity than exotic vegetables. This was probably due to the long distance of consumers to urban markets and little exposure to exotic types. However, it remained open if exotic vegetables were eaten instead of or in addition to traditional ones. Only for wild and exotic vegetables it was found through cluster analysis that they are not consumed together but substituted each other. (Keding 2010) Increasing the diversity within one food group such as vegetables does not necessarily lead to a greater consumption quantity when different types replace each other, however, it can be important for culinary art and cultural identity and in general ensure the consumption of this particular food group.

3.2. Dietary diversity: links to agricultural production and socio-economic values

In the same study in Tanzania, dietary diversity scores (DDS) of women were significantly associated with the number of vegetables that women cultivated/collected. In addition, those women who cultivated/collected vegetables more consistently (similar species richness year round), but also those who sold their products, had higher DDS. Consequently, not only the availability of agricultural diversity is linked to dietary diversity, but also the possibility of marketing agricultural products which would contribute to cash income that in turn can be spend on additional foods. (Keding et al. 2012)

Among the 252 participating women, vegetables were among those food groups consumed by nearly all year round; however, the amount of vegetables consumed decreased with increasing diversity in the diet. Less healthy and valuable food groups such as beverages and sugar accounted for a high dietary diversity and replaced the amount consumed of more healthy food groups such as vegetables. Consequently, different forms of an increase in dietary diversity must be distinguished. While a high nutritional diversity is usually desirable for a balanced diet it may not necessarily result in better health (Keding et al. 2012). Also others have argued that a certain degree of diversity does not mean that the dietary quality will match people's particular needs. Consequently, dietary quality and nutritional adequacy of diets should be of high significance (Brown et al. 2002). Therefore, dietary diversity scores should be either enhanced with a measure of dietary quality or used in combination with further measures of dietary quality and food quantity.

4. Conclusion

Fortunately, a growing number of research and development institutions currently realise the urgent need for multi-sectoral approaches to bridge the gap between agriculture, nutrition and health, to jointly tackle the triple burden of malnutrition and, thus, creating nutrition-

sensitive food and agricultural systems. For this, the common value chain approach needs to integrate environmental issues, such as soil, water and health hazards, intersectoral communication, knowledge production and education. Considering the source of foods, including also wild and neglected species, will be of similar importance as improving indicators for measuring dietary diversity. In general, agricultural biodiversity should play a key role in this process as it will not only ensure environmental sustainability but can contribute to nutritional adequacy of diets, cultural acceptability and – especially when traditional foods are considered – also to low cost accessibility of food, thus, creating sustainable diets.

Acknowledgements

For the Tanzanian study the unreserved cooperation and contributions of all participating women is highly acknowledged; as well as from the horticultural extension workers in the different districts; AVRDC-Regional Center for Africa and HORTI Tengeru staff; students and staff from Sokoine University of Agriculture, Morogoro; and supervisors and colleagues at the Universities of Giessen and Goettingen, Germany. Financial support by the German Federal Ministry for Economic Cooperation and Development/Deutsche Gesellschaft für Technische Zusammenarbeit (BMZ/GTZ), the German Academic Exchange Service DAAD and the Eiselen Foundation Ulm, Germany is gratefully acknowledged.

References

Amede, T., Stroud, A. & Aune, J. 2004. Advancing human nutrition without degrading land resources through modeling cropping systems in the Ethiopian highlands. *Food Nutr Bull* 25(4):344-53.

Arimond, M. & Ruel, M. T. 2004. Dietary diversity is associated with child nutritional status: evidence from 11 demographic and health surveys. *J Nutr* 134(10):2579-85.

Bezner Kerr, R., Snapp, S., Chirwa, M., Shumba, L. & R., M. 2007. Participaroty research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertiliy. . *Experimental Agriculture* 43:437-453.

Bioversity. 2011**.** Bioversity International Nutrition Strategy 2011-2021. Resilient food and nutrition systems: Analyzing the role of agricultural biodiversity in enhancing human nutrition and health. Pages 26. Bioversity International, Rome, Italy.

Briend, A., Ferguson, E. & Darmon, N. 2001. Local food price analysis by linear programming: A new approach to assess the economic value of fortified food supplements. *Food & Nutrition Bulletin* 22(2):184-189.

Brown, K. H., Peerson, J. M., Kimmons, J. E. & Hotz, C. 2002**.** Options for achieving adequate intake from home-prepared complementary foods in low income countries. *in* R. E. Black, M. K. Fleischer, eds. Public Health Issues in Infant and Child Nutrition. Nestec, Williams and Wilkins, Vevey/Lipincott, USA.

Cakmak, I. 2002. Plant nutrition research: Priorities to meet human needs for food in sustainable ways. *Plant and Soil* 247(1):3-24.

Deckelbaum, R. J., Palm, C., Mutuo, P. & DeClerck, F. 2006. Econutrition: implementation models from the Millennium Villages Project in Africa. *Food Nutr Bull* 27(4):335-42.

DeClerck, F. A., Fanzo, J., Palm, C. & Remans, R. 2011. Ecological approaches to human nutrition. *Food Nutr Bull* 32(1 Suppl):S41-50.

Fanzo, J., Cogill, B. & Mattei, F. 2012**.** Metrics of sustainable diets and food systems. Technical Brief - Madrid Roundtable. Bioversity International and Daniel and Nina Carasso Foundation, Rome, Italy.

FAO. 2011. Combating micronutrient deficiencies: food-based approaches. Food and Agriculture Organization of the United Nations and CABI International, Rome, Italy.

Frison, E. A., Smith, I. F., Johns, T., Cherfas, J. & Eyzaguirre, P. B. 2006. Agricultural biodiversity, nutrition, and health: making a difference to hunger and nutrition in the developing world. *Food Nutr Bull* 27(2):167-79.

Hadley, C., Mulder, M. B. & Fitzherbert, E. 2007. Seasonal food insecurity and perceived social support in rural Tanzania. *Public Health Nutrition* 10(06):544-551.

Hoddinott, J. & Yohannes, Y. 2002. Dietary diversity as a food security indicator. International Food Policy Research Institute, Food Consumption and Nutrition Division, Washington, USA.

Iannotti, L., Cunningham, K. & Ruel, M. T. 2009**.** Improving Diet Quality and Micronutrient Nutrition. Homestead Food Production in Bangladesh. IFPRI, Washington DC, USA.

IFPRI. 2011**.** Leveraging Agriculture for Improving Nutrition and Health. Highlights from an international conference. IFPRI, New Delhi, India.

Keding, G. B. 2010. Linking nutrition security and agrobiodviersity: the importance of traditional vegetables for nutritional health of women in rural Tanzania. Cuvillier Verlag, Göttingen, Germany.

Keding, G. B., Msuya, J. M., Maass, B. L. & Krawinkel, M. B. 2012. Relating dietary diversity and food variety scores to vegetable production and socio-economic status of women in rural Tanzania. *Food Security*(4):129-140.

Keding, G. B., Schneider, K. & Jordan, I. Nutrition-sensitive agriculture as a key concept for sustainable diets: challenges in production processing and utilisation of foods. Unpublished.

Keding, G. B., Weinberger, K., Swai, I. & Mndiga, H. 2007. Diversity, traits and use of traditional vegetables in Tanzania. AVRDC - The World Vegetable Center, Shanhua, Taiwan. 53 pp. pp.

Kennedy, G. L., Pedro, M. R., Seghieri, C., Nantel, G. & Brouwer, I. 2007. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. *J Nutr* 137(2):472-7.

Lyimo, M., Temu, R. P. C. & Mugula, J. K. 2003. Identification and nutrient composition of indigenous vegetables of Tanzania. *Plant Foods for Human Nutrition (Formerly Qualitas Plantarum)* 58(1):85-92.

Olney, D. K., Talukder, A., Iannotti, L. L., Ruel, M. T. & Quinn, V. 2009. Assessing impact and impact pathways of a homestead food production program on household and child nutrition in Cambodia. *Food Nutr Bull* 30(4):355-69.

Pinstrup-Anderson, P. 2012**.** The food system and its interaction with human health and nutrition. *in* S. Fan, R. Pandya-Lorch, eds. Reshaping agriculture for nutrition and health. International Food Policy Research Institute, Washington, D.C., USA.

Price, L. L. 2003**.** Farm Women's Rights and Roles in Wild Plant Food Gathering and Management in North-East Thailand. *in* P. L. Howard, ed. Women and Plants. Zed Books Ltd, London, UK.

Rah, J. H., Akhter, N., Semba, R. D., de Pee, S., Bloem, M. W., Campbell, A. A., Moench-Pfanner, R., Sun, K., Badham, J. & Kraemer, K. 2010. Low dietary diversity is a predictor of child stunting in rural Bangladesh. *Eur J Clin Nutr* 64(12):1393-8.

Ruel, M. T. 2003. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J Nutr* 133(11 Suppl 2):3911S-3926S.

Savy, M., Martin-Prevel, Y., Danel, P., Traissac, P., Dabire, H. & Delpeuch, F. 2008. Are dietary diversity scores related to the socio-economic and anthropometric status of women living in an urban area in Burkina Faso? *Public Health Nutr* 11(2):132-41.

Savy, M., Martin-Prevel, Y., Traissac, P. & Delpeuch, F. 2007. Measuring dietary diversity in rural Burkina Faso: comparison of a 1-day and a 3-day dietary recall. *Public Health Nutr* 10(1):71-8.

Schneider, K. & Hoffmann, I. 2011. Nutrition ecology--a concept for systemic nutrition research and integrative problem solving. *Ecol Food Nutr* 50(1):1-17.

Termote, C., Cogill, B., Deptford, A., Muguro, S., Kimere, C., Grace, J., Mutangah, J., Mattei, F. & Fanzo, J. 2013**.** Role of wild, neglected and underutilzed foods in reducing the cost of a nutritionally adequate diet in the eastern region of Baringo District, Kenya. Poster presented at Grand Challenges Exploration Agriculture and Nutrition Meeting, March 13-15 2013 in Seattle, WA. Bioversity International, Rome, Italy.

Thorne-Lyman, A. L., Valpiani, N., Sun, K., Semba, R. D., Klotz, C. L., Kraemer, K., Akhter, N., de Pee, S., Moench-Pfanner, R., Sari, M. & Bloem, M. W. 2009. Household dietary diversity and food expenditures are closely linked in rural Bangladesh, increasing the risk of malnutrition due to the financial crisis. *J Nutr* 140(1):18.

UN. 2012**.** Food and nutrition security for all through sustainable agriculture and food systems. Note from the United Nations System High Level Task Force on Global Food Security. United Nations, Rome, Italy.

Waage, J., Dangour, A. D., Hawkesworth, S., Johnston, D., Lock, K., Poole, N., Rushton, J. & Uauy, R. 2011**.** WP1: Understanding and improving the relationship between agriculture and health. Pages 96 Foresight Project on Global Food and Farming Futures. The Government Office for Science, London, UK.

Welch, R. M. 2008**.** Linkages between trace elements in food crops and human health. *in* B. J. Alloway, ed. Micronutrient deficiencies in global crop production. Springer Science+Business Media B.V., London.

Welch, R. M. & Graham, R. D. 1999. A new paradigm for world agriculture: meeting human needs: Productive, sustainable, nutritious. *Field Crops Research* 60(1â€“2):1-10.