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ORIGINAL PAPER

Ambiguity in a trans-disciplinary stakeholder assessment of neglected and underutilized species in China, Cambodia, Thailand and Vietnam

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Abstract Neglected and Underutilized Crop Species (NUS) are grown primarily by traditional farmers in developing countries. They were once more widely grown but are today falling into disuse for a variety of agronomic, genetic, economic and cultural factors. While these crops continue to be maintained by socio-cultural preferences and use practices, most of them remain inadequately characterized and neglected by research and conservation. The aim of our work was to improve the agricultural portfolio by identifying promising neglected and underutilised species in China, Cambodia, Northeastern Thailand and Northern Vietnam. We began with preparing a "Masterlist" containing 260 species, based on farmer interviews and literature review. After an initial pre-selection we identified

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17 NUS for China, 13 for Cambodia, 12 for Thailand, and 22 for Vietnam as of highest priority. These NUS then underwent a multi-criteria and trans-disciplinary assessment involving 511 stakeholders such as scientists, farmers, NGOs and policy makers. Based on the assessment we identified the most promising NUS for each country. We also identified some limitations for the promotion of so-called priority NUS regarding to some substancial disagreement between the involved stakeholders. In China and Cambodia, for example, farmers judged the potential of NUS significantly lower than other stakeholders, and in Vietnam scientists and policy makers had substantially different opinions on NUS compared to farmers. Addressing these ambiguous views will be highly relevant to the develoment of an improved agricultural portfolio.

Keywords Neglected and underutilized species · Trans-disciplinary assessment · Traditional farmers · Portfolio · China · Thailand · Cambodia · Vietnam

Introduction

Peace and the welfare of human society depend fundamentally on a sufficient, balanced and secure supply of food. Of the 7000 plant species used worldwide in food and agriculture, only 30 crops "feed the world". These are the crops that provide 95% of global plant-derived energy-intake (calories) and proteins. Wheat, rice and maize alone provide more than half of the global dietary energy. A further six crops or commodities—sorghum, millet, potato, sweet potato, soybean and sugar (cane/beet)—bring the total to 75% of the global energy intake (FAO 1997). When food supplies are analysed at the sub-regional level, however, a greater number of crops emerge as significant, such as beans, bananas, lentils, cowpea, yams, groundnut and pea that are the dietary staples of millions of the world's poorest people. Apart form these major and minor crops, lot of other potentially useful crops are hardly used due to cultural, agronomic or economic reasons. These so-called neglected and underutilized[1] species (NUS) receive relatively little development and research attention, although they provide large opportunities for society (Williams and Haq 2002; Dawson et al. 2007). These NUS are an important fraction of the agronomic portfolio, bearing an undiscovered economic potential and contributing essentially to agro-biodiversity, a cornerstone in the reliability of food supply. Conserving and using plant genetic diversity of the world's major crops is vital in meeting the world's future development needs, and their genetic resources are the focus of most conservation efforts. These efforts, however, might not be enough in ensuring food security, instead an "out-of-the-box" thinking is certainly required to improve the portfolio of agricultural production (Figge 2004). In addition the re-introduction, management and promotion of neglected and underutilized crop species (NUS) is highly important for future food security, and agricultural

[1] *Neglected crops* are those grown primarily in their centres of origin or centres of diversity by traditional farmers, where they are still important for the subsistence of local communities. Some species may be globally distributed, but tend to occupy special niches in the local ecology and in production and consumption systems. While these crops continue to be maintained by socio-cultural preferences and use practices, they remain inadequately characterized and neglected by research and conservation. *Underutilized crops* were once more widely grown but are today falling into disuse for a variety of agronomic, genetic, economic and cultural factors. Farmers and consumers are using these crops less because they are in some way not competitive with other crop species in the same agricultural environment. The general decline of these crops may erode the genetic base and prevent the use of distinctive useful traits in crop adaptation and improvement (IPGRI 2002).

diversification (Padulosi et al. 1999; Eyzaguirre et al. 1999; Padulosi 1999a, b; IPGRI 2002; Jaenicke and Höschle-Zeledon 2006).

Aim of the project

The major impetus to consider underutilized crops has come from a wider recognition that these crops collectively play vital roles in farming systems and in human wellbeing. This recognition has been slow, but swelling in strength since the Earth Summit in 1992, and supported by trends to make agriculture more environmentally sensitive, and sustainable. Other trends include an appreciation of economic development, requiring the involvement of social and ethical dimensions, the rights of indigenous peoples, appreciation by the genetic resources community of the input of farmers in selection, enhancement and conservation of agro-biodiversity, and by recognition of the need for more sustainable production systems, especially for fragile ecosystems. The aim of the project was therefore to assess the opinion of different stakholders on potential priority NUS in selected Asian countries, in order to support their sustaianable use, and contribute to agricultural diversification, income generation and food security on a regional and international level.

Geographic focus: China and Southeast Asia

Given the importance of NUS genetic resources for food security, and the fact that a high diversity of NUS is located in developing countries, our aim was to identify NUS in 4 selected Asian countries, namely: China, Cambodia, Thailand and Vietnam.

China is an important cradle of agriculture as well as a centre of origin and diversity for globally important crops such as rice (*Oryza sativa*) and soybean (*Glycine max*). China, however, maintains also a high diversity in traditional crops and crop wild relatives and is confronted with the risk of genetic erosion (Gao 2003; Schmidt and Wei 2006). Given that China is affected by ongoing socioeconomic and environmental changes (e.g. population growth, land use change) and the adoption of less and less high yielding varieties, the maintainance of traditional food plants and neglected and underutilised species is of great importance (USDA 2004; Deng et al. 2006).

Cambodia is the poorest and least developed country in our study and its agriculture and food supply is based almost exclusively on rice (see e.g. FAOSTAT 2006). Rainfed rice is predominantly grown in lowland but also in many upland areas. Besides rice there are some other varieties of other crops grown for home-consumption, local markets or industrial use (PDAC 2006). Government and donor-support through extension services, establishment of market linkages and research are, however, still dominated by activities in the rice- and rubber-sectors. This leaves almost all crops as neglected and underutilized in Cambodia. Further research on NUS is therefore of basic importance to Cambodian food security contributing to diversification of agriculture. The development of the agriculture sector has been an important element of the Royal Government's strategy to reduce poverty in rural communities, achieve food security, and foster equitable and sustainable economic growth. From a poverty eradication perspective, the most important policy-related objective regarding agriculture development is the improvement of household food security. Contributing to this objective and improving living standards more generally, market-based farming will be enhanced, given that 85% of the population lives in rural communities and 75% of the poor are farmer-headed households.

Vietnam is considered as one of the countries with the highest agro-biodiversity in the world. Although rice is the dominant crop in Vietnam and consequently, most policies and

techniques are focused on rice production. However, environmental issues are arising due to the overuse of fertilizers and pesticides, monocultures and biodiversity degradation, genetic erosion, high risk from yield loss and global climate change (Rambo 1998). On the other hand, minor crops such as NUS are less concerned by the Vietnamese government policies, although they bring significant contributions to food security and local livelihood, especially for disadvantages groups or ethnic minority people (Van Dinh et al. 2006).

Thailand. Our study focused on the Northeast that is the largest region of Thailand with approximately one third of both total land area and population of the country. Most of the people in the northeast are engaged in agriculture, of which 84% are depending on rainfed agriculture (Polthanee 2001). Farming in the northeast is traditional crop-based and the few major crops are sugarcane, cassava, maize, rice and rubber. Apart from these major crops, lots of neglected and underutilized species (NUS) are still important for the subsistence of local communities, but inadequately characterized and neglected by research and conservation (Polthanee 2001). The re-introduction, management and promotion of NUS is highly important for future food security, and agricultural diversification in the northeast to increase farmer income. The need for an improved agricultural portfolio is also stressed by the fact that recent changes in rainfall patterns in northeastern Thailand resulted in the need to abandon some crops as they cannot be grown any more under the current dry conditions.

Objectives

The main objective of our work was to elaborate a list of recommendations and strategies for the sustainable use of NUS in Asia and to include researchers, policy makers, NGOs and especially farmers in participating Asian countries. To reach the objective, we followed three major steps:

1. Gathering of information on NUS from the respective regions and prepare a masterlist containing all identified NUS, and preparing a criteria list for NUS assessment, including potential constraints[2] and opportunities for these species (von Maydell 1989; Lazaroff 1989; Padulosi 1999a, b). The inclusion of policy makers and farmers started at this early stage to ensure a higher level of commitment from these stakeholders.
2. Each NUS in our Masterlist underwent a pre-selection process by our team, and a limited number of other researchers, policy makers and farmers. A short list of NUS was selected for each country and a larger assessment was carried out including researchers, policy makers, some NGOs and especially farmers. The plant species were judged according to our criteria list and than ranked by their average judgements.
3. In the third and last step recommendations were elaborated on the basis of the NUS assessment to lead the way to an optimal knowledge transfer from science to NGOs, farmers and policy makers.

Methods

The investigations were carried out between September 2006 and August 2007. The structure of our work was the following:

[2] E.g. competitiveness, knowledge on uses, research on genetic diversity assessment and use, policy & legislation, traditional knowledge, market conditions, opportunities for commercialisation, farmer's income, propagation techniques, knowledge on cultural practices, attractive traits.

(1) Development of NUS masterlist for China, Cambodia, Thailand and Vietnam,
(2) Identification of selection criteria that capture the main constraints and opportunities for sustainable use of NUS, including scientific, cultural and policy issues,
(3) Pre-selection of NUS,
(4) Trans-disciplinary survey in China, Cambodia, Thailand and Vietnam with different stakeholders such as scientists, NGOs, policy makers but also traditional farmers in rural villages, to assess the pre-selected NUS,
(5) Analysis of assessment results and ranking of NUS,
(6) Preparation of recommendations on how to improve the sustainable use of NUS in each country.

NUS masterlist

A compilation of an extensive list of neglected and underutilized plant species for northeast Thailand, northern Vietnam, Cambodia and China was carried out based on literature review, national agricultural statistic books, analysis of gene bank accessions, exploratory interviews with representatives of the Ministry of Agriculture, farmers, researchers at universities and in agricultural research stations, and policy makers in Thailand, Cambodia, China and Vietnam. The species identified in all four countries were combined into one "masterlist" and the following information was added:

- Scientific name,
- Botanical familiy name,
- Common names in English, Chinese, Thai, Khmer, Vietnamese, and indigenous names;
- Information on occurence in China, Thailand, Cambodia, and Vietnam,
- Origin of species,
- Kind of use (with the categories: 1 = Cereal and pseudocereal; 2 = Legumes; 3 = Vegetables; 4 = Fruits and nuts; 5 = Medicinal, aromatic, stimulant, beverages; 6 = Industrial, construction; 7 = Forage and browse; 8 = Forest trees; 9 = roots and tubers),
- Part of plant used (with the categories: 1 = Fruit; 2 = Grain/seeds; 3 = Flower; 4 = Leaf; 5 = Root or tuber; 6 = Stem/bark; 7 = Whole),
- Type of plant (with the categories; 1 = Anual; 2 = Bi-anual; 3 = Perenial),
- Life form of plant (with the categories: 1 = Grass; 2 = Shrub; 3 = Tree; 4 = Climber; 5 = Root/tuber,
- And "other" important details not specified above, including pictures.

The masterlist included 260 species, from 82 families.

For an overview of the masterlist see Annex A.

Selection criteria

The selection criteria for the evaluation of NUS were adapted from Padulosi et al. 1999 (see Table 1). The pre-selected NUS were rated according to these six criteria. For the assessment we used a Likert-scale from 1 to 4 (1 = Very low; 2 = Low; 3 = High; 4 = Very high). For each NUS, in addition to the detailed assessment, we also needed to combine the six assessment criteria and calculated an average "general assessment" value (judgement mean and ± standard deviation).

Table 1 Final list of criteria to assess and select NUS

Criteria	Additional description
Economic and agronomic competitiveness	Potential generated income, changing abiotic and biotic conditions (e.g. climate, pests), attractive traits, lack of market/poor commercialisation
Local and national use, cultural acceptance	e.g. attractive traits
Traditional knowledge	Knowledge on cultural practices, propagation techniques, knowledge on uses
Scientific Knowledge	Research on genetic diversity, propagation techniques, knowledge on uses
Policy & legislation	Extension and research activities by Government and NGO's, favourable policies or government support
Opportunities for national/export niche market	Availability of existing or potential future markets in the region, neigboring countries or overseas

Pre-selection of NUS

In order to reduce the workload for the participants of the final NUS assessment, we carried out a pre-selection of NUS based on the Masterlist. For each country a short list of NUS was produced by the authors, acknowledging the importance of NUS and their cultivated area, especially paying attention to those species that can improve local sustainable development, environment and economics. The pre-selection was carried out with the help of researchers farmers and policy makers. See Table 2 for the number of species retained.

Trans-disciplinary survey and NUS assessment

The total number of involved stakeholders (farmers, policy maker, NGOs, scientists) was 511, of which the majority were farmers (363), followed by policy makers (82), scientists (54) and NGOs (12), see Table 3. On the field survey for the pre-selected species of NUS, two methods were employed.

1. For Thailand, Vietnam, Cambodia and in one case in China we went directly to the farmers and interviewed them directly.
2. For most of Chinese farmer interviews we asked colleagues in local governments for help. We sent them the questionnaire (with the plant species and the assessment criteria),

Table 2 Numbers of NUS for each country throughout the selection procedure

Category	China	Cambodia	Thailand	Vietnam
Species from the masterlist[a]	156	87	77	206
Pre-selected species[b]	17	13	12	22
Retained species in %	10.9	13.8	15.6	10.7

[a] The sum of these species is higher than total number of species in the masterlist, as species can be found in more than one country

[b] Two pre-selection steps were carried out in China, Cambodia and Vietnam. Some species were also excluded from the final list because they didn't match the full definition of NUS

Table 3 Number of stakeholders that participated in the assessment of NUS in our study

Country	Total	Scientists	Farmers	NGOs	Policy makers
China	231	33	189	0[a]	9
Vietnam[b]	51	17	28	0[a]	6
Thailand	39	4	31	1	3
Cambodia	190	0[a]	115	11	64
Total	511	54	363	12	82

[a] In Cambodia there is only one Agricultural University with few staff and most of them work on major crops, so no scientists were included. Few NGOs were contacted in China and Vietnam but they did not reply to our questions

[b] In Vietnam most scientists (13 out of 17) and some farmers (3 out of 28) participated only in the pre-seelction but not in the NUS assessment

and they assigned the questionnaire to the individual staff who worked in individual villages to get the answer.

The participants in the trans-disciplinary survey were recruted from the following background:

(a) CHINA

Scientists were from the following organisations (number of scientists in brackets):

Shenyang Agricultural University (1); Yunnan Agricultural University (1); Agro-forestry Academy of Beijing City (1); Agro-forestry Academy of Hebei Province (1); Bioversity International, China office (1); China Agricultural University (1); Chinese Academy of Tropical Agricultural Sciences (3); Hunan Agricultural University (1); Institute of Botany, the Chinese Academy of Sciences (2); Institute of Crop Sciences, Chinese Academy of Agricultural Sciences (4); Institute of Fruit Trees, Chinese Academy of Agricultural Sciences (1); Institute of Landscape Architecture of Beijing City (1); Institute of Medicinal Plant Development, Chinese Academy of Medical Sciences (1); Institute of Special Local Products, Chinese Academy of Agricultural Sciences (1); Northeast Agricultural University (1); Shandong Normal University (1); South China Botanical Garden, Chinese Academy of Sciences (1); Vegetable Institute of Hunan Province (1); Wuhan Botanical Garden, Chinese Academy of Sciences (1); Xinjiang Agricultural University (1); Zhejiang University (1).

Farmers were from the following provinces (number of farmers in brackets):

Beijing (7); Gansu (5); Guangdong (22); Guangxi Autonomous Region (10); Hainan (6); Hebei (3); Heilongjiang (12); Henan (10); Hunan (21); Jiangxi (10); Jilin (2); Liaoning (15); Shandong (25); Shanxi (15); Sichuan (16); Zhejiang (10). The investigated regions represent the main parts of the Chinese agricultural area.

NGO Though 15 NGOs were invited to evaluate the pre-selected NUS list, about five NGOs returned the receipt of email, three of them replied to explain reasons that blocked their response to the evaluation of NUS species. None of the NGOs provided the assessment. This suggested that the participating of NGOs should be improved.

Policy makers Agricultural Bureau of Ningxiang county, Hunan Province (3). Within the Ministry of Agriculture: Agricultural Technology Popularities and Application Centre, Department of Crops, Department of Market and Economics Information, Information Centre of the Ministry of Agriculture (2), Research Centre for Rural Economy.

(b) VIETNAM

Scientists Vietnamese Academy of Agricultural Sciences: Center for root crops (1); Institute for Plant Genetic Resources (2). National University of Hanoi (2).

Hanoi Agricultural University: Faculty of Agronomy (6); Institute for Ecology and Biological Resources (2): Department of Biotechnology (1); Institute for plant breeding (3); Department of medicinal plant resources, Institute for Medicinal Plants (1).

Policy maker and NGOs Hanoi Agricultural University, Institute of Policy and Strategy for Agricultural Development (2); and Department for Scientific management & International relations (1). Department of Cultivation, Ministry of Agriculture and Rural Development. Care International (1), and an Extension consultant for Asian Developments Bank's development program.

Farmer The survey was carried out in four locations, three in Nghe An province: Can hamlet (10), Huoi Giang hamlet (5), Son Ha hamlet (4) and one in Hoa Binh province: Tat hamlet (6).

(c) THAILAND

Scientists were from: Khon Kaen Field Crops Research Center, Khon Kaen; Faculty of Agriculture, Khon Kaen University; Ubon Ratchathani University, Ubon Ratchathani; Ubon Ratchathani Field Crops Research Center, Ubon Ratchathani; Ubon Ratchathani University, Ubon Ratchathani.

Farmer were from Chaiyaphum province (6); Burirum province (7); Roi-Et province (6); and Loei province (12).

NGO representative from Muang District, Mukdaharn.

Policy makers were from: Pitsanulok Field Crops Research Station, Pitsanulok; Chumpare Rice Research Station, Khon Kaen; and Chiang Mai Field Crops Research Center, Chiang Mai.

(d) CAMBODIA

Scientists: not included,

NGOs (incl FAO) GTZ: 2; Seila: 1; FAO: 1; CEDAC (Centre d'Etude de Développement Agricole Cambodgien): 7.

Policy makers were e.g. from the Agriculture ministry officers: Vice-director of Department of Agricultural extension: 1; Farming System office staff: 3; IPM staff (Integrated Pest Management): 6, and the provincial agriculture officers: 54 (including 6 directors or vice-directors of some provincial agriculture departments).

Farmers were from the following provinces (number of farmers in brackets): Part 1: Western part: Battambang, Siem Reap and Banteay Meanchey provinces (26); Part 2-Upland part: Steung Treng, Ratanakiri and Kratie provinces (35); Part 3-Eastern part: Svay Rieng province (5); Part 4-Southern part: Kampot, Kampong Speu and Takeo provinces (29); Part 5-Mekong area: Kampong Cham and Kandal provinces (20).

For a better geographical overview of the regions we included for the farmer interviews see Fig. 1.

Results

The results show the mean judgement value of the six evaluation critera for each NUS and each stakeholder group, plus a combined average of all stakeholders. The results are shown country by country.

China

For China we used three stakeholder groups for analysis, namely scientists, policy maker and farmer (no NGOs could be included). Based on the average judgement values of all

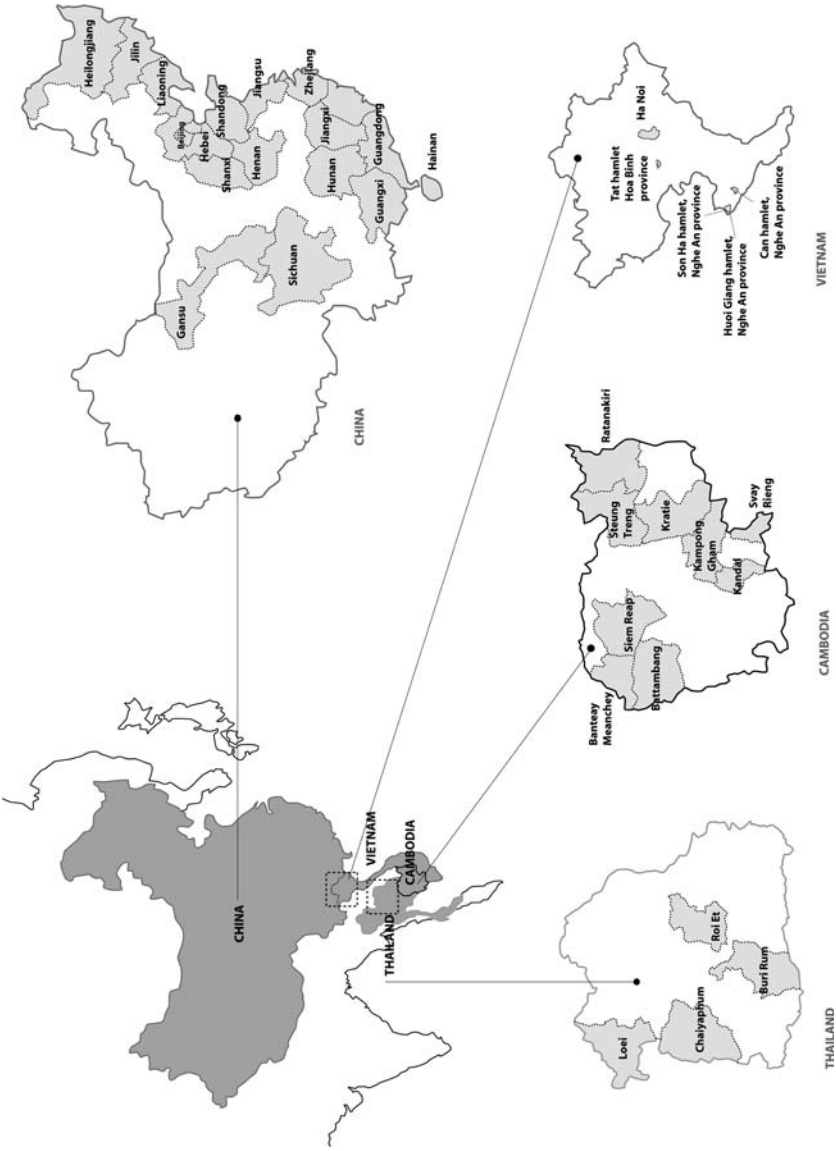

Fig. 1 Geographical overview of sites where interviews with farmers and regional policy makers were carried out. In Thailand only the northeast and in Vietnam only the northern region was included in our survey

stakeholders, out of the 17 NUS used in the Chinese survey, the most promising NUS were: buckwheat (*Fagopyrum esculentum*; average judgement value of policy maker, scientists and farmers: 3.0), followed by fleeceflower root (*Fallopia multiflora*; 2.93), and mulberry tree (*Morus alba*; 2.9). All of these NUS were judged higher by scientists than by farmers, and also policy maker judged them higher (with the exception of mulbery tree). See Fig. 2 for more details on the judgements of the three different groups. Another finding was that—combing all judgements for all NUS—the judement values of farmers were generally lower than that of scientists (see Fig. 3).

It has to be noticed that in China, from north to south and from east to west, there are large differences regarding ecological and climatic conditions, as well as in the economic situation and cultural habits. Due to this variability there is no single NUS that could be planted in all regions of China. In regions with habits to plant certain crops, farmers scored these species higher. For example cashew (*Anacardium occidentale*) received the highest score from farmers in Hainan among all surveyed provinces, but in the combined farmer results cashew is only rated as a mediocre NUS.

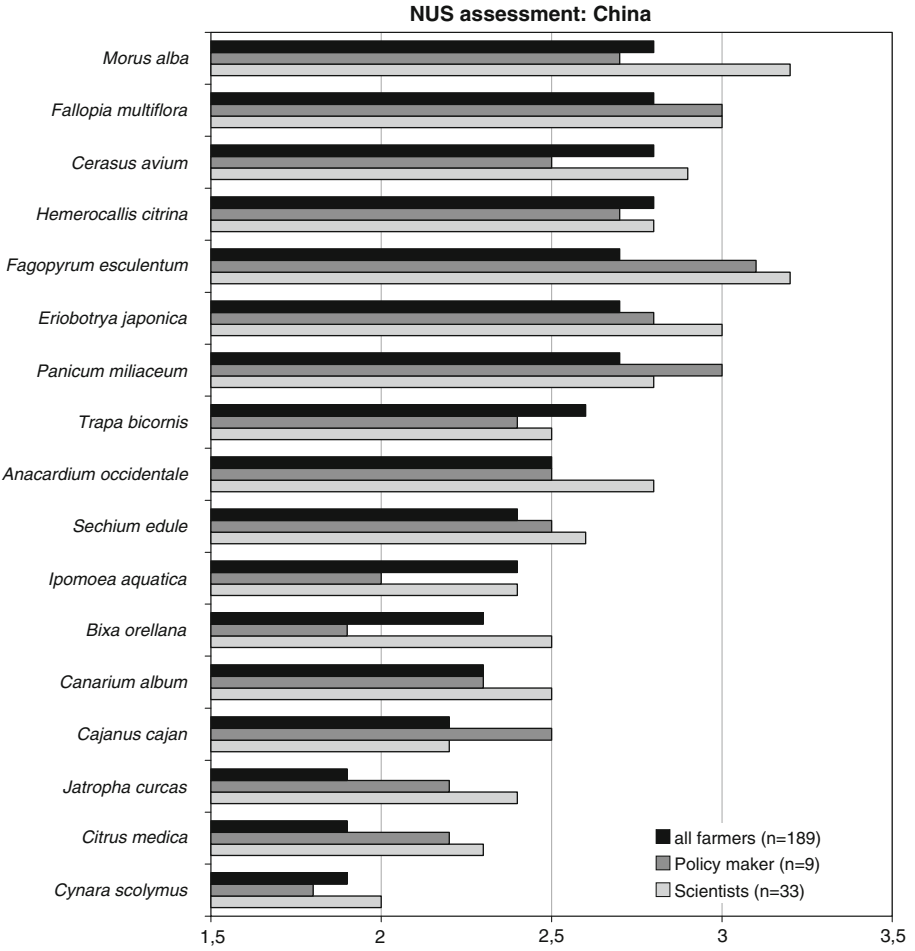

Fig. 2 Mean judgement values for 17 selected NUS in China, for scientists, policy maker and farmers. Judgement scale was from 1 (lowest) to 4 (highest)

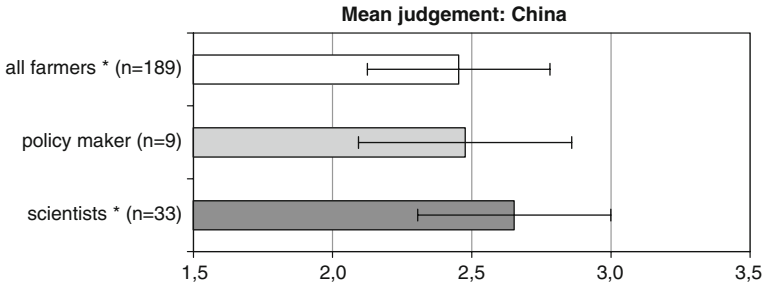

Fig. 3 Mean judgement values over all NUS for Chinese scientists, policy maker and farmers (including standard deviation). The asterix (*) indicated that the judgement difference between farmers and scientists is statistically significant at $P < 0.05$. Judgement scale was from 1 (lowest) to 4 (highest)

Cambodia

Given that Cambodian agriculture is heavily dependend on rice (FAOSTAT 2006) we acknowledged the inclusion of species that would under normal circumstances not be considered as NUS according to the definitions stated above. For example in Thailand there are many crops that are not considered as minor or underutilized, but these crops are considered as underutlized in Cambodia.

For Cambodia we used three stakeholder groups for analysis, namely NGOs, policy maker and farmer (no scientists were included). Out of the 13 NUS used in the Cambodian survey, the most promising NUS were: lemongrass (*Cymbopogon citratus*; average judgement value of policy maker, NGOs and farmers: 2.54), different varieties (yellow, sugar and green) of banana (*Musa* sp.; 2.50), mungbean (*Vigna radiata*; 2.38), sweet potato (*Ipomea batatas*; 2.34), taro (*Colocasia esculenta*; 2.33) and groundnut (*Arachis hypogaea*; 2.33). See Fig. 4 for details on the judgements of the three different groups. Cambodian farmers -on average- judged NUS much lower than did the other groups, especially NGOs (see Fig. 5).

In Cambodia, the specific NUS do not have the same importance in all investigated regions:

For instance, ginger (*Zingiber officinale*) can be grown well along the Mekong River area but it does not grow well in other regions, for instance in Kampong Speu province (Southern part of Cambodia). Durian (*Durio zibethinus*) can grow well in areas with a relatively low annual average temperature, and cashew is more important in upland areas and in Kampong Cham province (southeast), in the south of Cambodia it has less importance.

Northeast Thailand

In northeast Thailand only two stakeholder groups were used for analysis, as scientists, NGOs and policy maker were combined into one group, with farmers representing the second group. The results show that out of the 12 NUS used in the Thai survey the most promising NUS were: kenaf (*Hibiscus sabdariffa*; average judgement value of all stakeholders: 2.55), safflower (*Carthamus tinctorius*; 2.35), ricebean (*Vigna umbelata*; 2.35) and a second kenaf species (*Hibiscus cannaninus*; 2.30). See Fig. 6 for details on the judgements of

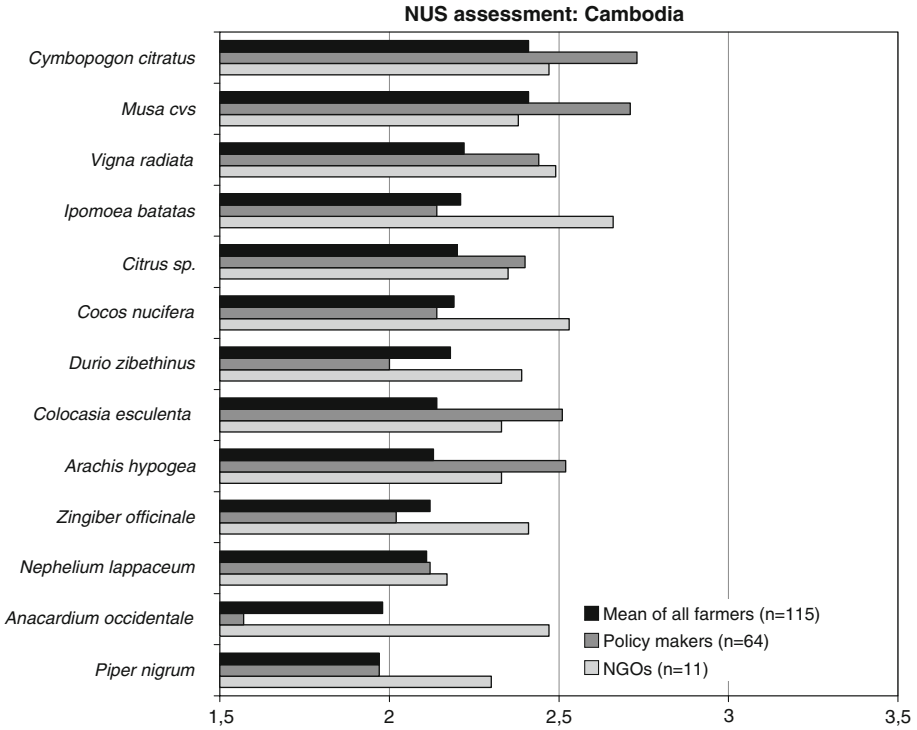

Fig. 4 Mean judgement values for 13 selected NUS in Cambodia, for NGOs, policy maker and farmers. Farmers judged NUS significantly lower than NGOs did. Judgement scale was from 1 (lowest) to 4 (highest)

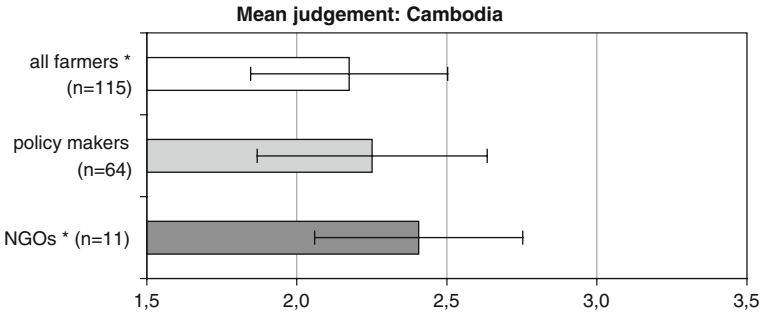

Fig. 5 Mean judgement values over all NUS for Cambodian NGOs, policy maker and farmers (including standard deviation). The asterix (*) indicated that the judgement difference between farmers and NGOs is statistically significant at $P < 0.05$. Judgement scale was from 1 (lowest) to 4 (highest)

the different groups. In contrast to China and Cambodia, farmers did not judge the NUS lower on average than the other stakeholder group.

Northern Vietnam

In northern Vietnam only two stakeholder groups were used for analysis, as scientists, NGOs and policy maker were combined into one group, with farmers representing the

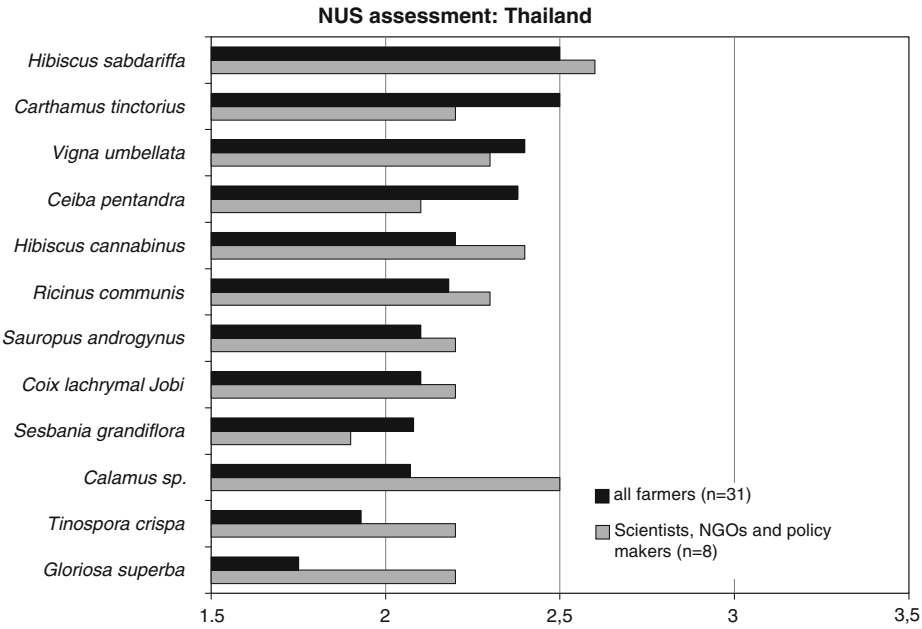

Fig. 6 Mean judgement values for 12 selected NUS in Thailand. Only two stakeholder groups were used her: farmers and a combined group of scientists, NGOs and policy makers. Judgement scale was from 1 (lowest) to 4 (highest)

second group. The results show that out of the 22 NUS used in the Vietnamese survey the most promising NUS (based on the average value of the two stakeholder group) were: litchi (*Litchi chinensis;* average judgement value: 2.97), leaf mustard (*Brassica juncea*; 2.91), and Chinese mustard (*Brassica campestris*; 2.85). See Fig. 7 for details on the judgements of the different groups. Although no significant difference in the overall mean NUS judgement of farmers and the other stakeholder group could be found, there was a high number of single NUS where the two groups differed considerably in their judgement. Given that the values on Likert-scale could only be between 1 and 4, a difference in judgement of more than one point can be considered as high. Compared to the results of China, Cambodia and Thailand where the differences between the stakeholder judgement never were higher than 1 point in the 4 point Likert-scale for any of the NUS, Vietnam had such high differences with several different NUS. In three other cases the farmers judged the NUS much higher than the scientists: edible canna (*Canna edulis*; mean judgement difference: 1.3), taro (*Colocasia esculenta*; 1..25) and lablab *Lablab purpureus*; 1.2). See Fig. 7 for details on the judgements of the different groups.

Cross border similarity

Among the NUS selected for trans-disciplinary assessment only few showed up in more than one country. For example Chinese white olive (*Canarium album*) was selected for both China and Vietnam, taro (*Colocasia esculenta*) for Vietnam and Cambodia, cashew (*Anacardium occidentale*) for China and Cambodia, and star goosbery (*Sauropus androgynus*) for Thailand and Vietnam.

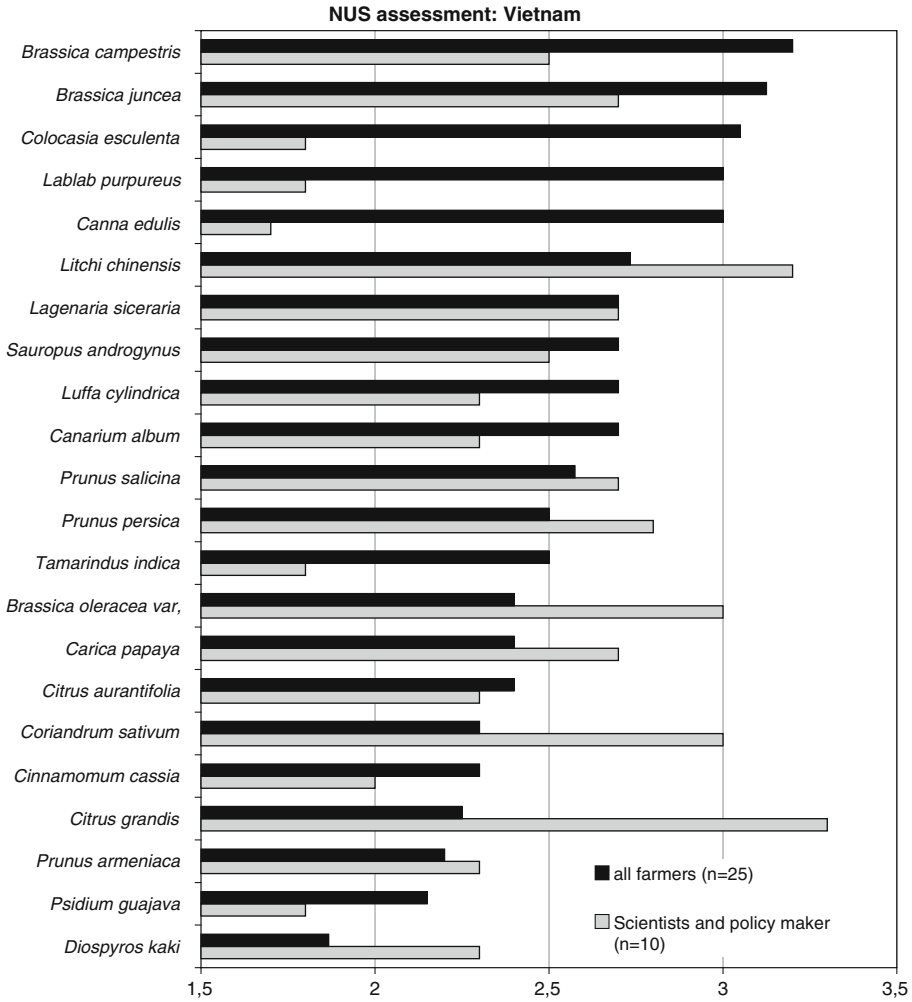

Fig. 7 Mean judgement values for 22 selected NUS in Vietnam. Only two stakeholder groups were used her: farmers and a combined group of scientists, and policy makers. For several NUS the mean judgement difference between the two groups was larger than 1. Judgement scale was from 1 (lowest) to 4 (highest)

Discussion

General discussion

Problems and risks faced by developing and transition countries in Asia include e.g. the globalisation of agricultural markets, poverty and lack of funding to participate in international research activities, loss of agricultural biodiversity (genetic erosion), large socio-economic changes, and provision of acceptable food safety and quality. Although there is apparently no silver bullet to solve all of these problems, a diversification and improvement of the agricultural portfolio is without doubt necessary to face at least some of the environmental

and socio-economic challenges ahead. Only a diversified agricultural portfolio represents a robust agricultural food and non-food production system able to resist expected and unexpected future changes such as climate change or socio-economic changes, thus being crucial for farmers and the whole society (Dawson et al. 2007).

It is well known that NUS face several challenges that impede their increased use, among those the six most important: (1) lack of regional or global markets, (2) lack of scientific knowledge, (3) lack of traditional knowledge, (4) low cultural acceptance, (5) poor agronomic competitiveness, and (6) lack of adequate policy support and favourable legislations (Padulosi et al. 1999). Trying to overcome these challenges is an extremely difficult task and done with a lot of energy by different organisations, e.g. the Global Facilitation Unit for Underutiluzed Species (GFU), or the International Center for Underutilized Crops (ICUC). Still, in addition to these already identified challenges there might be another one that could effectively impede the increased use of NUS. This additional challenge is the ambiguity in the views of different stakeholders involved such as farmers, agricultural scientists, policy makers and NGOs working with NUS. This ambiguity might actually counterbalance the valuable work done to overcome the six previously mentioned challenges.

As can be seen from our results from China and Cambodia (but not so in Thailand and Vietnam) farmers generally lack the confidence in and optimism about the potential of neglected and underutilized species, when compared to agricultural scientists (China) or NGOs (Cambodia). In Vietnam there is much stronger disagreement between farmers and other stakeholders when compared to China, Cambodia and Thailand. Thailand was the only country in our study where farmers and other stakeholder groups did not have (or had only minor) ambiguous views on the future potential of different NUS. More details on the different countries will be discussed in the following chapters.

China

Though there are no specific policies in China regarding the utilization and protection of NUS, some of the policies concern the preservation of major species resources and the utilization of species conserved in minority regions. The central government has set up several programs and gives importance to the research on biological resources and the conservation of biodiversity. On the basis of the suitability of NUS for the different ecological conditions all over the country, the obtained knowledge should be transferred to farmers without delay and distortion. In general interaction and cooperation between farmers and other stakeholders such as scientists and policy maker (including extention workers) should be improved. Also those NUS species, which were subject to extensive research and are considered as profitable and environmentally friendly species, but which are not being recognized by local farmers, should be recommended to farmers and encouraged to be planted. Demonstration fields should be established in order to promote the popularity of the targeted NUS, which are traditionally not well known. Prices and production quantities on national and international markets should be collected and made available to farmers via institutions that are supported by the government. The agricultural departments should provide technical support to farmers as well as guidelines for the development of organic farming. The avoidance of synthetic pesticides and chemical fertilizers in cultivating these NUS species should be highly encouraged and recommended to enable a sustainable development. In China the government should establish special organizations to work on the improvement of the NUS utilization. A mechanism to link all concerned ministries should also be constructed in order to facilitate the conservation and utilization of NUS.

Growth and management technologies should be developed in scientific studies in order to be made available to farmers. It should be encouraged that the potential value of the NUS that is currently not available to people is revealed through scientific research.

Communication, however, should not be unilateral and only top-down from scientists or policy makers to farmers, but a dialogue should be established that considers farmers as equal partners.

Cambodia

The assessments for NUS by farmers, NGOs and policy makers (including provincial agriculture officers) were noteably different. Generally, the farmers of each area provided lower judgement values while the provincial agriculture officers provided higher judgement values regarding some of the criteria. For instance, for government promotion or new technology, the farmers provided lower judgement values as they are hardly visited by the extension officers. The reasons for this are that, in most cases, new techniques for some crops or vegetables or information about new crops are provided by agriculture officers only to farmers who live in or nearby the town (where the agriculture officers are based). For this reason, the provincial agriculture officers (policy makers) provided higher scores for the NUS assessment than farmers. In contrast, the interviewed farmers who live far away from the town in a remote area provided lower scores due to the inaccessibility of new techniques. Although the extension workers and field staff are employed to work with farmers, in most cases, it is impossible to mobilize them because of a lack of resources such as fuel for vehicles. There is also a lack in facilities (e.g. training centers and demonstration farms) and networks to disseminate technology, and the linkages between research, development and extension are weak. Therefore, the extension service—the most important link between science, government and the farmers—is weak overall. As a result, farmers have limited awareness of and access to agricultural technologies, and hence have poor skills and knowledge in agricultural production. Even though the Ministry of Agriculture of Cambodia has a large staff, it is not able to mobilize it effectively. Management is weak, many staff member have limited skills and experience, and low salaries are a major disincentive to them (Cambodia is one of the poorest countries in the world). Coordination with and influence over other agencies and stakeholders are limited. For these reasons, the ministry has difficulties in achieving its sectorial objectives. Weak extension and research capacity in agriculture constrains technical support and information flow to farmers. As a result, the farmers' knowledge and skills remain low, and they are unable to benefit from technical opportunities or new crops. Institutional weaknesses also constrain the distribution and marketing of agricultural products, resulting in unfair trade and unsafe food, for example.

There is at the moment no policy on NUS in Cambodia and most research tends to be on rice-based farming systems and on rubber. Only a handful of agricultural research-institutes exist in Cambodia and the largest, the Cambodian Agricultural Research and Development Institute (CARDI) focuses mainly on rice, with some other activities in mungbean, tomato and maize. The Kbal koh vegetable research station develops new varieties and produces good quality seeds of tomato, maize, mungbean and some less known vegetables. The Rubber Research Institute is mainly conducting research on rubber and rubber-based production systems. As an effect there is a lack of information concerning indigenous crop-species including germ plasm collection and general production information.

Thailand

The result of the assessment for NUS crops obtained from scientists, policy makers and NGO is mostly similar in all four provinces investigated. The unambiguous view is probably due to the fact that scientists, policy makers and NGO frequently visit farmers and exchange information about these crops. Some NUS crops are important for all regions such as *Hibiscus sabdariffa*, and *Ricinus communis*, while others are only significant in some specific regions.

At the moment there is no national research policy that specifically addresses NUS. Most of the national policies are aimed at high international and national trading value crops. Nowadays, Thailand imports NUS products in large amounts from abroad. Therefore, a policy should be developed with regard to an equitable sharing of benefits arising from the use of NUS, with the communities concerned. Local research institutes need to include NUS in the genetic resource list of ex-situ or in-situ conservation for breeding materials. More funding should be provided for research and development in view of improving technologies to increase yield, quality and economic efficiency, as well as of searching for new products and adding value to particular NUS.

In general, the researchers at local level organize meetings on NUS. However, the communication and awareness should go far beyond scientific publication. Strengthening of linking knowledge among researchers, extension workers and farmers of NUS will be of great importance. Further improving farmers' knowledge on NUS through information technology is also necessary in the near future using e.g. Tambon and District Administrative Organization and Tambon Technology Transfer Center.

Vietnam

Over the past 10 years, Vietnam has become the second largest rice exporter in the world. Consequently, almost all policies are launched to promote the productivity and quality of commonly used crops such as rice or maize to ensure food security. In contrast, all NUS have currently only limited market output (low price, poor marketing network) and policy support for NUS production is still insufficient. And in case there is support they are mainly based on external consideration without needs assessment from local farmers. Also cultural factors and site specific conditions are still not highly considered. Post harvest technique and information are still insufficiently available to farmers. These are likely to be some of the reasons why the results from Vietnam exhibit a clear disagreement between farmers and scientists/policy makers on the future potential of many NUS. They only agree in the fact that policy support for NUS is insufficient.

As there is unequal awareness or understanding on NUS values from policy makers, NGOs, scientists and local people, the government should train farmers to improve their awareness on the functions of NUS. Care has to be taken, however, that communication should not be unilateral and only top-down from scientists or policy makers to farmers, but instead a dialogue should be established that considers farmers as equal partners.

The government should encourage all stakeholders such as farmers, scientists, policy makers, NGOs to develop strategies for a sustainable use of NUS and preventing genetic erosion. Among those strategies home gardening should be a point of interest.

NUS and the impact of modern biotechnology

An underutilized species that is frequently mentioned as a promising crop for medical purposes is *Artemisia annua*[3], as it has anti-malaria properties. *A. annua* (for its chemical

compound artimisinin) has been used for over two millennia in Chinese traditional medicine. There seems to be great hope that *A. annua* could be positive example or even a kind of "flagship NUS". On its website the International Center for Underutilized Crops says for example:

> The potential of Artemisia and other species has generated much interest and they have recently become the focus of attention by Western research and international agencies such as the WHO. Several locally-made products have been recently released. In the first quarter of 2006 alone, a 2-month electronic discussion forum dedicated to Artemisia was moderated by the Dutch Royal Tropical Institute (KIT), and at the same time a workshop was held about herbal anti-malarials by the World Agroforestry Centre (ICRAF).

Such initiatives to promote the use of *A. annua* could, however, easily be counterbalanced through modern approaches of biotechnology, in particular synthetic biology[4], which is why we didn't choose this plant to be included in our study. A Californian based research group in 2006 (funded by a 42 Mio US$ grant by the Bill and Melinda Gates Foundation) announced that synthetic production in engineered yeast was already capable of producing artemisinic acid at a significantly higher specific productivity than *A. annua* (Ro et al. 2006) and far more cost-effective. It can be foreseen that advances in synthetic biology could lead to a further progress in low-cost production of formerly only plant derived chemical compounds, which will ultimately lead to a loss of incentive to grow these affected NUS.

Final conclusion

Today, NUS marketing is limited in terms of commercialization and demand. Improvement of seed processing and marketing opportunities, particularly niche market should be identified (Jaenicke and Höschle-Zeledon 2006). Although NUS cannot not (yet) be considered as economic crops, they are environment-friendly, promoting soil erosion control and improving soil fertility. In addition, NUS can act as additional food crops to prevent micronutritient deficiency and as medicinal plants. They can also help to generate labour income for farmers throughout the year (Dawson et al. 2007). The NUS selected in our study for the trans-disciplinary assessment and the recommendations for their improved sustainable use, should help scientists to focus on the R&D of these species to overcome the current lack of knowledge, it should also help policy makers to enable suitable policy measures on the species level. Given that appropriate communication with farmers can be established it can guide farmers to use alternative crop species to diversify the agricultural portfolio to increase food security, open up opportunities for income generation in niche markets for farmers in China and Southeast Asia.

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[3] See e.g. http://www.icuc-iwmi.org/examples.htm as of September 27, 2007.

[4] For background information on synthetic biology see e.g. http://syntheticbiology.org/FAQ.html

Annex A: Comprehensive overview of the 260 species used in our masterlist

The following abbrevations are used:

Occurence: CN: China; CM: Cambodia; TH: Thailand; VN: Vietam.

Use: F/N: fruits and nuts; M: medicinal/aromatic/stimulant/beverages; F/B: forage and browse; F: forest trees; V: vegetable; R/T: roots and tubers; I/C: industrial/construction; L: legumes.

(1) *Achras zapota:* CM, VN; F/N, M; (2) *Acrocephalus indicus*: CN, VN; M; (3) *Actinidia* spp.: CN, F/N, F/B, F; (4) *Aeglos marmelos sqoamosa/reticulata*: CN, CM, VN; V, M; (5) *Aerva sanguinolenta*: VN; V, M; (6) *Allium ascalonium*: TH, VN; V, R/T; (7) *Allium porrum*: TH, VN; V, I/C; (8) *Allium ramosum*: VN; V; (9) *Allospondias lakonensis*: VN; F/N, M; (10) *Alocasia* spp.: CN, VN; M, I/C, R/T; (11) *Alpinia galanga*: CN, CM, M; (12) *Alpinia officinarum*: VN; M; (13) *Amarantus spinosus*: CN, TH, VN; V, M, I; (14) *Amomum* spp.: VN; M; (15) *Ampelopsis cantoniensis*: VN, M; (16) *Anacardium occidentale*: CN, CM, TH, VN; F/N, M, I/C; (17) *Ananas comosus*: CN, CM, TH, VN; F/N; (18) *Andrographis paniculata*: CN, TH, VN; M; (19) *Anethum graveolens*: VN; M; (20) *Annona muricata*: CN, CM, TH, VN; F/N, M, I/C; (21) *Annona reticulata*: CN, CM, VN; F/N; (22) *Annona squamosa*: CN, CM, F/N, M, I/C; (23) *Aquilaria malaccensis*: VN; M, F; (24) *Arachis hypogaea*: TH, L; (25) *Areca catechu*: CN, CM, TH, VN; M; (26) *Artocarpus altilis*: CM, F/N, I/C; (27) *Artocarpus heterophyllus*: CN, CM, VN; F/N, M; (28) *Artocarpus* sp.*:* CN, VN, F/N; (29) *Asparagus officinalis*: CN, TH, VN; V, M; (30) *Averrhoa carambola*: CN, CM, VN; F/N, M; (31) *Azadirachta indica*: CM, TH, VN; V, M; (32) *Baccaurea ramiflora*: CM, VN; F/N; (33) *Barleria lupulina*: TH, M; (34) *Basella alba:* CN, VN; V, M; (35) *Basella rubra*: VN; V, F/N, M; (36) *Belamcanda chinensis*: VN; M; (37) *Benicasa hispida*: CN, CM, TH, VN; V, F/N; (38) *Bixa orellana*: CN, VN; I/C; (39) *Borassus aethiopicum*: CM, TH, VN; F/N, M, I/C; (40) *Borassus flabellifer*: CN, F/N, M, I/C; (41) *Brassica campestris*: TH, VN; V; (42) *Brassica gongylodes*: TH, VN; V; (43) *Brassica juncea*: VN; V, M; (44) *Buddleja officinalis*: VN; M; (45) *Cajanus cajan*: CN, CM, TH, VN; L, V, M, F/B; (46) *Calamus merillii*: CM, TH, VN; C, M; (47) *Calamus* sp.: TH, C, M; (48) *Cananga odorata var. odorata*: CN, VN; I/C; (49) *Canarium album*: CN, VN; F/N, M, I/C; (50) *Canarium pimela*: CN, VN; F/N, M, I/C; (51) *Canarium* spp.: CN, CM, VN; F/N, M, I/C, F; (52) *Canarium tramdenum*: VN; (53) *Canavalia* spp.: CN, VN; L, V, F/B; (54) *Canna edulis*: VN; L, M, F/B; (55) *Capsicum annuum*: VN; V; (56) *Carica papaya*: CN, CM, TH, VN; V, F/N, M, I/C; (57) *Carthamnus tinctorius*: TH, VN; M; (58) *Carya cathayensis*: CN, CM, F/N, M, I/C, F; (59) *Ceiba pentandra*: CN, CM, TH, VN; C, M; (60) *Cerasus avium*: CN, F/N; (61) *Cerasus* spp.: CN, F/N; (62) *Ceratonia siliqua*: CN, L, V; (63) *Chenopodium album:* CN, VN; C, L, V, Medicinal, F/B; (64) *Chrysanthemum* spp.: CN, VN; V; (65) *Chrysophyllum cainito*: CN, CM, VN; F/N, M; (66) *Chukrasia tabularis*: VN; I/C, F; (67) *Cibotium barometz*: CN, VN; M; (68) *Cinnamomum cassia*: VN; M, F/B; (69) *Citrullus lanatus*: CN, CM, TH, VN; F/N, M; (70) *Citrus aurantifolia*: CN, CM, VN; F/N; (71) *Citrus grandis and other citrus*: CN, CM, TH, VN; L, F/N, M; (72) *Citrus ichangensis*: CN, VN; F/N; (73) *Citrus limon*: CN, CM, VN; F/N; (74) *Citrus limonia*: CN, VN; F/N; (75) *Citrus maxima*: CN, CM, VN; F/N; (76) *Citrus medica*: CN, CM, VN; F/N; (77) *Citrus reticulata*: CN, CM, VN; F/N; (78) *Citrus sinensis*: CN, CM, VN; F/N; (79) *Citrus aurantium*: CN, VN; F/N, M; (80) *Clausena cambodiana*: CM, M; (81) *Clausena lansium*: CN, VN; F/N, M; (82) *Cleome gynandra*: CN, VN; M; (83) *Coccinia grandis*: CN, VN; F/N, M; (84) *Cocos nucifera*: CM, F/N, M, I/C; (85) *Coix lachryma jobi*: CN, CM, TH, VN; C, M, F/B; (86) *Colocasia antiquorum*: CN, C, V; (87) *Colocasia esculenta*: CN, CM, VN; M, F/BR/T; (88) *Colocasia gigantea*: VN; R/T; (89) *Corchorus* spp.*:* CN,

TH, VN; V, M, I/C; (90) *Cordyline fruticosa*: VN; R/T, I/C; (91) *Coriandrum sativum*: CN, VN; V, M; (92) *Cucurbita pepo*: TH, VN; V, M; (93) *Cuphea* spp.*:* CN, M; (94) *Curcuma* spp.*:* CN, TH, M; (95) *Curcurbita moschata*: CM, TH, VN; V; (96) *Cyamopsis*: CN, L, F/B, M, I/C; (97) *Cymbopogon citratus*: TH, VN; V, M; (98) *Cynara scolymus*: CN, VN; V; (99) *Dendrocalamus membranaceus*: VN; I/C, ; (100) *Dimocarpus longan*: CN, CM, TH, VN; F/N, M, I/C; (101) *Dioscorca persimilis*: VN; M, R/T, I/C; (102) *Dioscorea alata*: CN, CM, C, M, I, R/T; (103) *Dioscorea brevipetiolata*: CM, R/T; (104) *Dioscorea cirrhosa*: CN, VN; R/T; (105) *Dioscorea hispida*: CN, CM, TH, VN; M, R/T; (106) *Dioscorea pentaphylla*: CN, CM, V, M, I/C; (107) *Diospyros kaki*: VN; F/N, M; (108) *Dolichos lablab*: TH, VN; L; (109) *Dracaena angustiflora*: VN; M; (110) *Drynaria fortunei*: VN; M; (111) *Durio zibethinus*: CN, CM, TH, VN; F/N, M; (112) *Echinochloa frumentacea*: CN, C; (113) *Elaeis guineensis*: TH, I/C; (114) *Elentherine subaphylla*: VN; Medicinal; (115) *Eleusine coracana*: CN, TH, VN; C, I/C, F/B; (116) *Embilica officinalis*: CN, CM, VN; V, F/N, M, I/C; (117) *Emilia* spp.: CN, VN; M; (118) *Eriobotrya japonica*: CN, VN; F/N, M, I/C, F; (119) *Eryngium foetidum*: VN; M; (120) *Euphorbia* sp.: VN; Industrial; (121) *Euryale ferox*: CN, F/NF/B; (122) *Fagopyrum cymosum*: VN; M, R/T; (123) *Fagopyrum esculentum*: CN, C, M, F/B; (124) *Fallopia multiflora*: CN, VN; M, R/T; (125) *Ficus elastica*: VN; F/N, F; (126) *Ficus fulva*: VN; F/N, M; (127) *Ficus* sp.: CN, VN; F/N; (128) *Foeniculum vulgare*: CN, VN; V, M; (129) *Fragaria ananassa*: CN, TH, F/N; (130) *Garcinia mangostana*: CN, CM, TH, VN; F/N, M; (131) *Garcinia mutiflora*: CN, VN; F/N, M; (132) *Gloriosa superba*: CN, CM, TH, VN; M; (133) *Gossipium* sp.: TH, I/C; (134) *Gynura crepidioides*: VN; V, M; (135) *Gynura* spp.: CN, M; (136) *Heleocharis dulcis*: CN, VN; V, M; (137) *Helianthus annuus*: TH, C; (138) *Hemerocallis citrina*: CN, V, M, I/C; (139) *Hibiscus cannabinus*: CM, TH, VN; I/C; (140) *Hibiscus sabdariffa*: CM, TH, VN; I/C; (141) *Homalomena occulta*: CN, VN; M; (142) *Hordeum vulgare*: TH, C; (143) *Hovenia dulcis*: CN, CM, VN; F/N, M, I/C; (144) *Hura crepitans*: VN; M, I/C; (145) *Hylocerus undatus*: CM, VN; F/N; (146) *Ipomoea aquatica:* CN, CM, TH, VN; V; (147) *Ipomoea batatas*: CN, CM, TH, VN; C, R/T; (148) *Jasminum subtriplinerve*: VN; M; (149) *Jatropha curcas*: CN, CM, VN; M, I/C; (150) *Jussiaea repens*: CM, VN; C, M; (151) *Justicia gendarussa:* VN; M; (152) *Kalanchoe brossfeldiana*: VN; M; (153) *Lablab purpureus*: CN, VN; L, V, M; (154) *Lactuca indica:* VN; V, M; (155) *Lactuca sativa*: CN, CM, VN; V; (156) *Laempferia galanga*: CN, CM, VN; M; (157) *Lagenaria siceraria*: CN, VN; V, M; (158) *Lathyrus* spp.: CN, VN; L, F/B; (159) *Limnophila aromatica*: CN, TH, VN; V, M, ; (160) *Litchi chinensis*: CN, CM, TH, VN; F/N, M, I/C; (161) *Livistona cochinchinensis*: VN; I/C; (162) *Llex kaushue*: VN; M, I/C; (163) *Luffa cylindrica*: VN; L, V; (164) *Malva crispa*: CN, V; (165) *Mangifera indica*: CN, CM, TH, VN; F/N, M, I/C; (166) *Manihot esculenta*: CN, CM, TH, VN; I/C, R/T; (167) *Maranta arundinacea*: CN, CM, VN; I/C, R/T; (168) *Mazus pumilus*: VN; V, M; (169) *Melia azedarach*: CN, VN; M, F; (170) *Melientha suavis*: VN; V; (171) *Metroxylon sagu:* VN; C; (172) *Momordica charantia*: CN, CM, TH, VN; V, F/N; (173) *Momordica* spp.: CN, VN; V, M; (174) *Moringa oleifera*: CN, CM, TH, VN; V, F/N, M, I/C, F; (175) *Morus alba*: TH, F/N, M; (176) *Mucuna* spp.: CN, L, M, F/B; (177) *Musa cvs.:* CM, F/N; (178) *Musa uranoscopus:* VN; F/N, M, R/T; (179) *Nelumbo nucifera*: CM, VN; V, F/N, M, R/T; (180) *Nephelium lappaceum*: CN, CM, TH, VN; F/N, M, I/C; (181) *Nervilia* spp.: VN; , M; (182) *Nymphoides indica*: CN, CM, VN; V; (183) *Ocimum basilicum var. basilicum*: CN, CM, TH, VN; V, M, I/C; (184) *Ocimum temiflorum*: VN; C, M, I/C; (185) *Opuntia dilleni*: VN; C, M, R/T; (186) *Orthosiphon aristatus*: TH, VN; M; (187) *Orthosiphon* sp.: CN, M; (188) *Pachyrhizus erosus*: CN, TH, VN; L, M; (189) *Paederia scandens:* VN; M; (190) *Panax notoginseng*: CN, M; (191) *Panax vietnamese:* VN; M; (192) *Panicum miliaceum*: CN, TH, VN; C, I/C, F/B; (193) *Parthe-*

nium argentatum: CN, I/C; (194) *Paspalum scrobiculatum*: CN, VN; C, F/B; (195) *Passiflora edulis*: CN, CM, TH, VN; F/N, M, I/C, F/B; (196) *Perilla frutescens var.frutescens*: CN, VN; V, M; (197) *Peristrophe bivalvis*: VN; M; (198) *Persea americana:* CN, CM, VN; F/N, M; (199) *Phaseolus vulgaris*: CN, CM, TH, VN; L, F/N; (200) *Piper betle*: VN; M; (201) *Piper lolot*: VN; M; (202) *Piper nigrum*: CN, CM, TH, VN; F/N, M; (203) *Pistacia* sp.: CN, VN; I/C; (204) *Plantago major*: VN; M; (205) *Polygala tatarinowii*: CN, VN; M; (206) *Pouteria sapota*: VN; F/N, M; (207) *Prunus armeniaca*: CN, F/N, M; (208) *Prunus mume:* VN; F/N, M; (209) *Prunus persica*: VN; F/N; (210) *Prunus salicina*: CN, VN; F/N, M; (211) *Psidium guajava*: CN, CM, TH, VN; C, F/N, M, I/C; (212) *Psophocarpus tetragonolobus*: CN, VN; L; (213) *Pueraria mirifica*: TH, M; (214) *Pueraria montana var. chinensis*: VN; V, M; (215) *Punica granatum*: CN, CM, VN; F/N, M, I/C; (216) *Pyrus pyrifolia*: VN; F/N, M; (217) *Raphanus sativus*: TH, V; (218) *Rhodomyrtus tomentosa*: CN, VN; F/N, M; (219) *Ricinus communis*: CN, CM, TH, M, I/C; (220) *Rubus alceaefolius*: CN, VN; F/N, M; (221) *Salacca secunda*: CN, F/N; (222) *Salacca zalacca*: CN, CM, VN; F/N, I/C; (223) *Sansevieria trifasciata*: VN; I/C; (224) *Saurauia* sp.: CN, VN; F/N; (225) *Sauropus androgynous*: CN, CM, TH, VN; C, M; (226) *Sechium edule swartz*: VN; V; (227) *Sesamum indicum*: CN, CM, TH, VN; C, M; (228) *Sesbania grandiflora*: CN, CM, TH, VN; C, M; (229) *Setaria italica*: CN, TH, VN; C, M, F/B; (230) *Smilax glabra*: CN, VN; M; (231) *Solanum torvum*: CN, TH, VN; M; (232) *Solanum tuberosum*: VN; L, M, I/C; (233) *Strobilanthes cusia*: VN; M, I/C; (234) *Styrax tonkinensis*: VN; F, M; (235) *Syzygium jambos*: CN, CM, F/N; (236) *Tagetes erecta*: VN; M; (237) *Tamarindus indica*: CN, CM, TH, VN; L, F/N, M, I/C, F; (238) *Terminalia koernbachii*: CN, CM, VN; F/N; (239) *Theobroma cacao*: TH, I/C; (240) *Thysanolaena latifolia*: VN; I/C; (241) *Tinospora crispa*: CM, TH, M; (242) *Titiacora triandra:* TH, C, M; (243) *Toona sinensis*: CN, M, I/C, F; (244) *Torreya grandis cv.merrillii*: CN, I/C, F; (245) *Trapa bispinosa*: CN, VN; M, Forage, and, brose; (246) *Triticale*: CN, I/C; (247) *Vernonia* spp.*:* CN, M; (248) *Vigna angularis*: CN, VN; L, M; (249) *Vigna radiata*: CM, L; (250) *Vigna umbellata*: CN, CM, TH, VN; C, L, M; (251) *Vigna unguiculata cv. group sesquipedalis*: CN, CM, VN; L, V, F/N; (252) *Vitis* spp.: CN, CM, TH, VN; F/N, I/C; (253) *Vitis vinifera:* CN, CM, VN; F/N; (254) *Xanthoceras sorbifolia*: CN, I/C, F; (255) *Zanthoxylum nitidum*: CN, VN; M; (256) *Zingiber officinale*: TH, V, M; (257) *Zizania caduciflora*: CN, VN; V; (258) *Ziziphus jujuba*: CN, VN; F/N; (259) *Ziziphus jujuba var.spinosa*: CN, VN; F/N, F; (260) *Zizyphus mauritiana*: CN, CM, VN; F/N, M;

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