Paddy and Water Environment
https://doi.org/10.1007/s10333-018-0656-9

EDITORIAL

Rice ecosystem services in South-east Asia

Josef Settele[1,2,3] · Kong Luen Heong[4] · Ingolf Kühn[1,5,3] · Stefan Klotz[1,3] · Joachim H. Spangenberg[1,6] · Gertrudo Arida[7] · Alexis Beaurepaire[5] · Silke Beck[8] · Erwin Bergmeier[9] · Benjamin Burkhard[10,11,12] · Roland Brandl[13] · Jesus Victor Bustamante[14] · Adam Butler[15] · Jimmy Cabbigat[14] · Xuan Canh Le[16,17] · Josie Lynn A. Catindig[18] · Van Chien Ho[19] · Quoc Cuong Le[19] · Kinh Bac Dang[20,21] · Monina Escalada[22] · Christophe Dominik[8] · Markus Franzén[1,23] · Oliver Fried[9] · Christoph Görg[8,24] · Volker Grescho[1,25,3] · Sabine Grossmann[1] · Geoff M. Gurr[26,27] · Buyung A. R. Hadi[18] · Huu Hai Le[28] · Alexander Harpke[1] · Annika L. Hass[29] · Norbert Hirneisen[30] · Finbarr G. Horgan[31,32] · Stefan Hotes[13,2] · Yuzuru Isoda[33] · Reinhold Jahn[34] · Helen Kettle[15] · Anika Klotzbücher[1,34] · Thimo Klotzbücher[34] · Fanny Langerwisch[35] · Wai-Hong Loke[36] · Yu-Pin Lin[37] · Zhongxian Lu[38] · Keng-Yeang Lum[36] · Damasa B. Magcale-Macandog[2] · Glenn Marion[15] · Leonardo Marquez[7] · Felix Müller[10] · Hung Manh Nguyen[16] · Quynh Anh Nguyen[39] · Van Sinh Nguyen[16,17] · Jürgen Ott[1,40] · Lyubomir Penev[41,42] · Hong Thai Pham[17,43] · Nico Radermacher[44] · Beatriz Rodriguez-Labajos[45] · Christina Sann[46] · Cornelia Sattler[1] · Martin Schädler[1,3] · Stefan Scheu[44] · Anja Schmidt[1] · Julian Schrader[29,47] · Oliver Schweiger[1] · Ralf Seppelt[8,3] · Kukiat Soitong[48] · Pavel Stoev[41,49] · Susanne Stoll-Kleemann[50] · Vera Tekken[50,51] · Kirsten Thonicke[35] · Bianca Tilliger[45] · Kai Tobias[52] · Y. Andi Trisyono[53] · Thanh Truong Dao[39] · Teja Tscharntke[29] · Quang Tuan Le[16] · Manfred Türke[54,3,55] · Tomáš Václavík[8,56] · Doris Vetterlein[1,34] · Sylvia 'Bong' Villareal[18] · Kim Chi Vu[57] · Quynh Vu[1,12,58] · Wolfgang W. Weisser[54] · Catrin Westphal[29] · Zengrong Zhu[4] · Martin Wiemers[1]

Received: 27 May 2018 / Revised: 27 May 2018 / Accepted: 28 May 2018

Rice ecosystem services and LEGATO

The present special issue of Paddy and Water Environment (PAWE) focuses on Ecosystem Services in Irrigated Rice Landscapes as dealt with in the project "LEGATO—Land-use intensity and Ecological enGineering—Assessment Tools for risks and Opportunities in irrigated rice based production systems'' (Settele et al. 2015; http://www.legato-project.net/). The project aimed at advancing long-term sustainable development of irrigated rice landscapes against risks arising from multiple aspects of global change. It encompassed 20 contract partners from six countries and two international organisations as core members as well as numerous associated partners and/or advisory board members (see addresses of authors). LEGATO was part of the framework programme 'FONA—Research for Sustainability' (a funding scheme of the German Federal Ministry of Education and Research—BMBF) and was supported by GLUES—the scientific coordination and synthesis project (http://modul-a.nachhaltiges-landmanagement.de/en/scientific-coordination-glues/).

✉ Josef Settele
josef.settele@ufz.de

Extended author information available on the last page of the article

LEGATO followed the framework of the Millennium Ecosystem Assessment (MA 2005) by selecting characteristic elements of three MA service strands for analyses: (a) Provisioning Services: primary production, plant diversity, crop yield; (b) Regulating and Supporting Services: biocontrol, pollination and nutrient cycling; and (c) Cultural Services: cultural diversity and aesthetics/beauty. The analysis of ecosystem services was embedded in studies of socio-cultural and economic backgrounds, local as well as regional land use intensity and biodiversity, and the potential impacts of future climate and land use change.

As core output, LEGATO developed generally applicable principles of Ecological Engineering (EE), adapting, testing and implementing them under the given local socio-cultural conditions, for the stabilisation and improvement of agricultural production under future climate and land use change. EE is an emerging discipline, concerned with the design, monitoring and construction of ecosystems and aims at developing strategies to optimise the delivery of ecosystem services by enhancing natural regulation mechanisms instead of suppressing them (see also Gurr et al. 2003; Mitsch 2012; Horgan et al. 2016). Along these lines, LEGATO further aimed at generating new knowledge bases for decision making in the area of sustainable land management and livelihoods, including the support of governance and management

Published online: 04 July 2018

strategies, technologies and system solutions (Truong et al. 2016).

Co-design of research and co-production of knowledge

LEGATO was organised in Work Packages (= WPs) and followed the work flow shown in Fig. 1. The core elements of the project structure were the feedback loops, particularly those in relation to the co-design of research involving stakeholders which directly influence recommendations and implementations—often via several feedback loops (co-design: feedback WPs 1 with WP 2/3; and co-production for practical outputs, like Ecological Engineering: feedback WP 5 with WPs 2/3 and 4).

Our experience with this approach is mostly positive and has been analysed in more detail by Görg et al. (2014) and Spangenberg et al. (2018a, b; both in this issue). The main conclusions are that large integrated research projects are necessary to address the complexity of nature–society interactions within biodiversity research and beyond. Such large-scale research projects create additional challenges in terms of management and knowledge integration, but also offer promising opportunities for transdisciplinary research, if managed properly. For an appropriate integration of knowledge across different disciplines and with stakeholders, however, clarity of purpose from the onset is as decisive as ongoing two-way communication between researchers and non-academic partners in order to succeed in developing solutions for complex societal problems (Siew et al. 2016). Such a two-way communication goes beyond more linear outreach and dissemination activities which are often performed in conventional project management.

Thus, the exceptional characteristic and highlight in LEGATO was the close collaboration with farmers and other local stakeholders (i.e. the development of partnerships which are necessary to achieve real progress in the field of sustainable agriculture; Settele 2010). All research sites comprised farmers' fields, selected in close interaction with these farmers and with their enormous ongoing support, despite establishing experiments. In total, interactions with different groups of stakeholders and the number of people involved in each group can be summarised as follows (estimates from August 2015; see also Förster et al. 2015):

- Government institutions (Agriculture: 10; Environmental protection: 5; Municipal administration: 20; Tourism and culture: 20; general/top level: 20).
- Private sector (Business catering for the local market: 40; Business catering for the national and international market: 5).
- NGOs: 5.
- International organisations: 20.
- Individual farmers and land owners: 500.

Study regions and sites for field-based research

As solutions elaborated within the funding scheme were expected to be transferable to other regions, LEGATO opted for a trans-regional and international approach. The Philippines and Vietnam are particularly suitable, as they have important similarities as well as differences in a region of critical importance for global development: (a) Vietnam is a highly dynamic growth region; (b) the Philippines are heavily affected by demographic change; (c) Vietnam is a Buddhist country, while the Philippines is mostly Catholic, and both countries are ethnically very diverse; (d) both are climate sensitive regions (extreme weather and climate-dependent areas of irrigated rice production in Asia, with high vulnerability to climate); (e) the Philippines imports while Vietnam exports rice. The topological similarities allowed the selection of comparable transects in both countries along gradients which reflect different land system archetypes (Václavík et al. 2013,

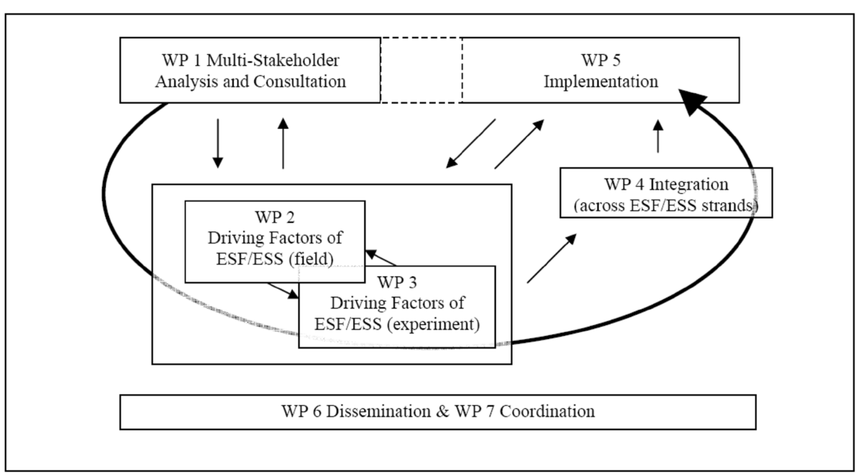

Fig. 1 LEGATO overview structure and work flow—the basis for co-design and co-production. (*Source*: Settele et al. 2018)

2016; Lin et al. 2018) with changing geo-climatic conditions and land use intensities, and also different levels of socioeconomic and cultural diversities (see Table 1 in Spangenberg et al. 2018a, this issue). They range from mountain areas via fertile hilly lowlands to low-lying, flood prone high production areas. In both countries, the mountain areas are characterised by terrace agriculture practised by indigenous people. The final selection of study regions was based on results of focus group discussions and interviews with stakeholders, resulting in a selection of seven regions (15 × 15 km^2 each), three in Luzon/Philippines, three in North Vietnam and one in the southern Vietnamese Mekong Delta. A map is shown in Fig. 2 (see also Fig. 1 in Klotzbücher et al. 2015a), for further details on respective climatic, land-use and soil characteristics, see Klotzbücher et al. (2015a) and for future scenarios of climate and land use, see Langerwisch et al. (2018). Vegetation in paddies and bunds mainly consists of weedy communities (Fried et al. 2017) with a clear increase in species richness from lowlands to mountains (Fried et al. 2018; this issue).

In each of the seven regions, ten core sites were selected in order to create sufficient data for scientifically robust comparative analyses (see also Table 1 in Klotzbücher et al. 2015a). The 10 sites were arranged in pairs, leading to five core study 'landscapes' (with each landscape consisting of a pair of rice fields or 'core sites'). Hence, we had 70 rice fields in total. One site of each pair was located in an agriculturally more intensively used setting (structurally poor, homogenous surroundings with more than 50% of the area within a radius of 100 m covered by rice fields), henceforth called "monoculture rice field". The second site was situated in 300–1000 m distance providing a more heterogeneous surrounding (structurally rich, less than 30% rice field area within a radius of 100 m and a higher proportion of non-intensively used areas, such as house gardens, fallows, forests), henceforth called "structurally diverse rice field". The selection is based on the hypothesis that higher structural diversity leads to higher biodiversity, enabling us to test biodiversity effects in irrigated rice agro-ecosystems. These two categories were also compared with an "agroforest" field within the rice growing areas on most of the sites (resulting in 5 triples per region; see Fig. 3).

Selections were made in close consultation with local administrators and LEGATO collaborators. This enabled us

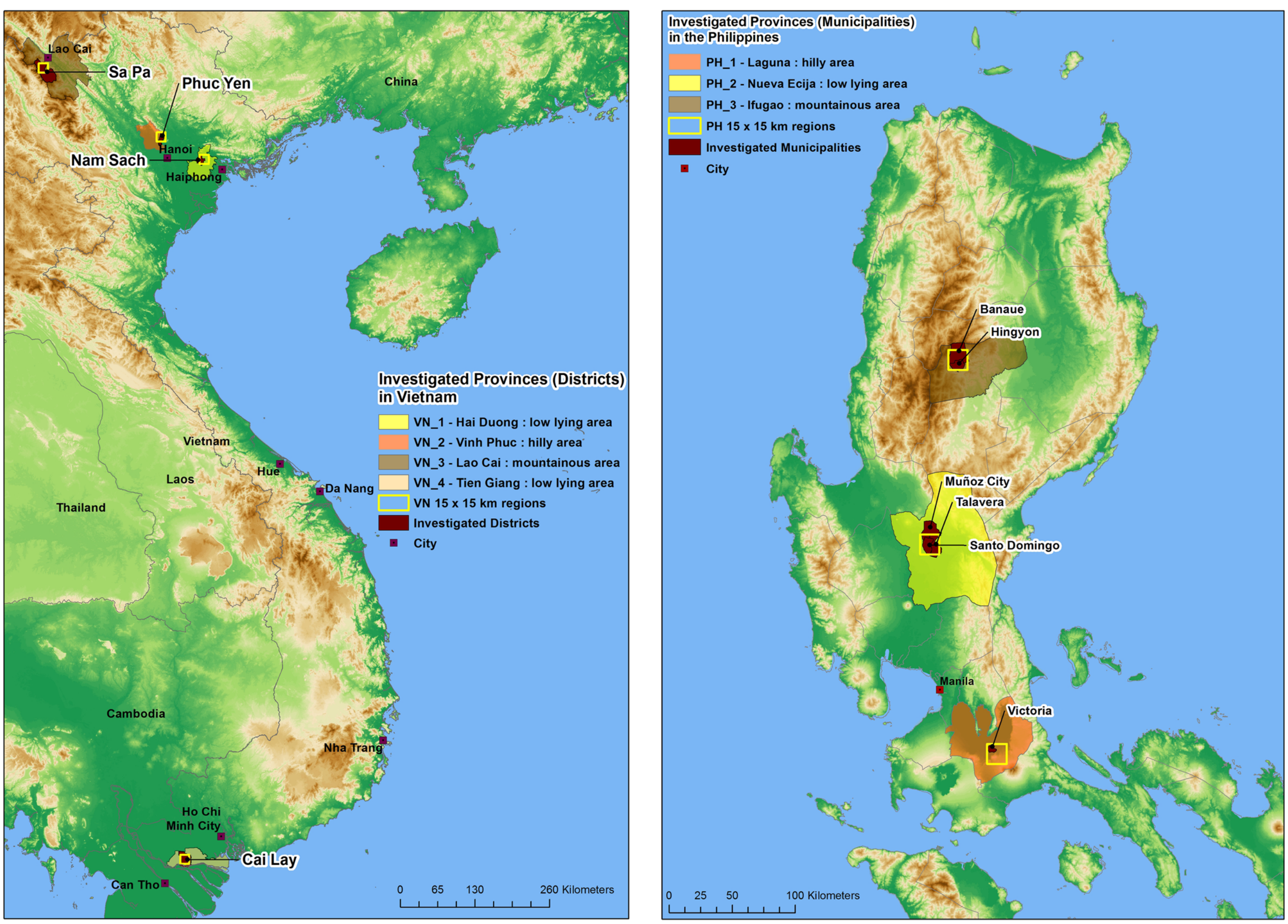

Fig. 2 Geographical distribution of the 7 LEGATO research regions VN_1–4 denotes investigation sites in different landscapes of Vietnam, PH_1–3 in the Philippines. (© Harpke/Grescho, UFZ; after Settele et al. 2018)

Fig. 3 The three habitat types investigated in LEGATO—exemplified for research region Laguna, Philippines (PH_1; see Fig. 2); left: "monoculture rice field" (© C. Sann), center: "structurally diverse rice field" (© A.L. Hass), right: "agroforest" (© A.L. Hass)

to include local communities with partly similar and partly different socio-cultural and economic characteristics, with the latter allowing for comparative analyses, while similar conditions provided a good baseline for social research (e.g. comparison of topographic pictures to identify terraced landscapes).

Regarding the economic situation of farmers, a clear gradient correlated with the biophysical landscape setting. In the mountainous regions of both Vietnam and the Philippines, only one harvest per year is possible, resulting in severe limitations to the agricultural income potential (due to topography, an increase in agriculturally usable area is unfeasible). Agriculture in Ifugao (region PH_3; see Fig. 2) hardly ever uses pesticides, although some farmers consider it as a "convenience option", while in Vietnam government instructions and the subsidy of agrochemicals led to an increasing usage (Sattler et al., 2018, this issue). While Ifugao was dominated by self-cultivated traditional rice varieties, in Lao Cai (region VN_3; see Fig. 2), mountain farmers followed governmental advice and turned to high yielding varieties (an important economic decision as seed is by far the most expensive input in both countries, at least as long as irrigation water is available at low cost). The limited yield potential forces many inhabitants to look for additional sources of revenue unless they are supported by government subsidies (like free rice deliveries in case of severe shortages in Vietnam). Additional income can come from jobs either outside the region, or non-agricultural ones, but directly related to it, within the region (like trading seeds and yield, rice processing, maintenance of agricultural equipment) or from jobs indirectly benefitting from the speciality of this agro-ecosystem (tourism including hotels, restaurants, tour guides, mobility services, etc.). In the hilly areas outside the mountain regions, small to medium scale agriculture dominated, with field sizes in Vietnam often below 1 ha. While small-scale farming was a family affair (although the younger family members did not work in the fields on a regular basis, but came as helping hands in the most labour intensive phases of the growth cycle), medium- to large-scale farming in the lowlands was usually conducted by farm workers. The farmers themselves acted mainly as managers, in Vietnam producing for the global market, in the Philippines for the domestic one.

Economic progress was assessed separately in and between countries: limited change happened in the mountain regions, while elsewhere the mood towards economic progress was grossly positive (with some exemptions in the Philippines). Vietnamese expected a steady improvement of their living conditions (although these differed greatly between genders as our group interviews showed—they were held separated for men and women).

Farmers in all regions hoped to gain additional benefits from adding ecotourism to their activity portfolio. This appeared as a rather natural extension of the existing ecotourism in Ifugao and the ethnic tourism in Lao Cai, although the impacts of ecotourism on indigenous communities are disputed (Coria and Calfucura 2012). It came as a surprise, however, when ecotourism was articulated as a future option by the pesticide intensive farmers in the lowlands.

Ecosystem service research

Provisioning services

The analysis of soil processes as the basis for rice production was one major topic in the LEGATO research on provisioning ESS. The focus of the research activity was on management of silicon (Si) availability, which has become widely recognised for being a crucial nutrient for rice plants (Guntzer et al. 2012). Various forms of potentially available Si in topsoils as well as the Si uptake rates by rice plants were assessed for all LEGATO core sites (Klotzbücher et al. 2015a, 2016), which resulted in a clear differentiation between Vietnam with low, and the Philippines with high Si availabilities. These differences can be explained by geo-/pedological conditions. The high Si availability in Philippine soils is mainly due to a large release of mobile Si by weathering processes in these areas of volcanic origin during recent geologic history. In some Vietnamese sites, the concentrations of plant-available Si in the topsoil were below critical values proposed in literature (Marxen et al. 2016), suggesting that Si might limit the growth of the rice plants. Addition of Si fertilizers (silica gel) enhanced the Si uptake and growth of rice plants at one Si-deficient site in Northern Vietnam (Marxen et al. 2016), yet showed no effects at another site in Southern Vietnam (Klotzbücher et al. 2018a, this issue). The reasons for the different responses of rice plants to Si fertilisation between sites are uncertain and deserve the attention of future research. Marxen et al. (2016) demonstrate that rice straw decomposition is an important source of plant-available Si. Hence, the removal of this straw from the fields after harvest, a frequent practice in Vietnam, can reduce the amount of Si available for rice plants. Litter decomposition processes by biota or Si in and outflow through water management (i.e. irrigation schemes) is another important determinant of Si availability in paddy soils (Klotzbücher et al. 2015b; Schmidt et al. 2016). Another surprising finding was that the variable Si uptakes of rice plants across the LEGATO core sites also affected lignin concentrations in the plants (Klotzbücher et al. 2018b). Incorporation of Si as a structural component in rice plants possibly substitutes the energetically more expensive biosynthesis of lignin. As lignin also regulates the decomposability of organic matter in soil, these results suggest that Si is a significant, but hardly recognised factor in organic carbon cycling in rice ecosystems.

In general, the decomposition of organic material is an important source of nutrients in agro-ecosystems. Schmidt et al. (2015a) studied invertebrate decomposers and showed that they substantially contribute to the decay of rice straw in paddy fields and thus might play an important role in soil fertility and site productivity. Their efficiency was shown to be highest near the field borders indicating a positive effect of surrounding structures on decomposer invertebrates. Further, crop residue management practices were found to significantly influence the decomposition activity of invertebrates and alter their community structure (Schmidt et al. 2015b). However, invertebrate abundance showed no correlation with decomposition rates. Effects of different size classes of soil and aquatic organisms on rice straw decomposition were further tested in a microcosm experiment (Panteleit et al. 2018, this issue). The experiment confirmed the relevance of macro- and meso-invertebrates for decomposition, and it highlighted the role of diversity of decomposer communities for enhancing decomposition rates. Future studies should evaluate in more detail how land management practices and landscape diversity contribute to the maintenance of ecosystem services provided by decomposer invertebrates, such as nutrient cycling and soil fertility, and develop appropriate trade-offs with other management issues, such as pest control or adaptation to climate change (Langerwisch et al. 2018). This is also relevant, as the Vietnamese government plans to promote the merging of fields and farms to larger units to enhance mechanisation opportunities and compensate for declines in the farming population. The LEGATO results (as outlined in the previous paragraph) show that such policies entail the risk of reducing nutrient cycling ESS, with a subsequent risk of declining soil fertility and yields.

Regulating services

While some modelling and mapping of natural hazard regulating ecosystem services has been conducted for Sapa, Lao Cai Province, Vietnam (Bac et al., in review), as well as some general land-cover based assessments (Burkhard et al. 2015), the focus within LEGATO was on species interactions on the landscape and field scale. There regulating services play a key role. Insect predators, such as damselflies and dragonflies, are important predators for example on rice pests such as plant- and leafhoppers (Ott 2015). Recently, outbreaks of key herbivore pests have increased significantly throughout Asia, mainly due to a lack of natural enemies—with the latter being largely an effect of increased pesticide applications (Heong et al. 2015; Spangenberg et al. 2015a). The ultimate reason for these trends is a narrow and thus counterproductive and self-defeating perception of causality chains: the standard logic considers insects as the initial problem, spraying insecticides as an adequate response resulting in yield protection and being supported by positive effects in the early growth phase. However, insecticide treatments not only impact pest populations, but also dramatically reduce the number of biocontrol organisms and in some cases cause direct plant-mediated increases in pest abundance (Horgan et al. 2017a, b; Gurr et al. 2016): The trade-off for such a short-term success is increased system sensitivity to subsequent infestations. As an example one may look at the case of golden apple snails (*Pomacea canaliculata*), one of the main pests in rice agriculture (Türke et al. 2018). For farmers the easiest way to control for their abundances appears to be the application of synthetic 'instant kill' molluscicides. However, these pesticides do not only have detrimental effects on the environment and non-target species (like insect predators), but are a serious threat to human health (Schneiker et al. 2016). Furthermore, it is a common practice to apply insecticides at the beginning of the rice cycle which, by reducing natural enemy numbers, can lead to severe damage during the later growth stages (e.g. due to planthopper infestations; Spangenberg et al.

2015a) resulting in even greater yield losses. Moreover, insecticide use is also harmful for pollinators, potentially leading to lower yields of insect pollinated crops within the rice landscape that provide additional income or nutritional diversity for farmers. Overcoming such misguided perceptions of land management options, these perceptions' foci and their impacts play a crucial role in establishing sustainable land use patterns.

To counteract the detrimental effects of ongoing land-use intensification in rice production systems on human and ecosystem health (Keune et al. 2017), these agro-ecosystems need to be managed in a more sustainable manner aiming at conserving and enhancing biodiversity and the provisioning of ecosystem services (Godfray and Garnett 2014). Westphal et al. (2015) reviewed management options for multiple ecosystem services and evaluated the merits of mass media campaigns and participatory approaches for more sustainable rice production. Generally, the implementation of flower strips within EE programs is one potential option to enhance pest regulation, pollination and cultural services, such as recreation (Blaauw and Isaacs 2014; Tschumi et al. 2015; Stallman 2011). Flowering vegetable crops grown on rice bunds have been shown to increase parasitism of rice stemborers (Vu et al. 2018, this issue) and attract wild birds that feed on damaging caterpillars and apple snails (Horgan et al. 2017a, b). Knowledge gained from LEGATO on the impact of non-rice crops on the natural enemies of important rice pests such as planthoppers and stemborers (e.g. Arida et al. 2016; Horgan et al. 2017a, b; Dominik et al. 2018; Sann et al. 2018a, b) will support the further development of diversified rice landscapes that preserve efficient and resilient biocontrol functions. Furthermore, increased knowledge of the rice bunds as habitat for flowering plants (Fried et al. 2018; this issue), including species that could potentially provide nutrients and refuges for natural enemies, will help engineer rice paddies to better support natural pest regulation. As experienced within LEGATO, rice farmers need to participate in the development, research and evaluation of ecological engineering programs (Spangenberg et al. 2018b, this issue). Westphal et al. (2015) conclude that comprehensive EE programs are needed, which combine participatory approaches, mass media campaigns and flower strip implementation to motivate farmers and to increase the sustainability of rice production in Asia and to enhance ES.

However, besides the addition of semi-natural habitats like flower strips, the heterogeneity of the farmland itself is also crucial for the maintenance of ecosystem services. Hopper parasitoids greatly benefit from heterogeneous rice productions landscapes. Sann et al. (2018a) could demonstrate that spatially and temporally variable rice crops in different stages and ratoon rice can sustain vital populations of egg parasitoids (Chalcidoidea) and thus high levels of biological control of important rice pests. Moreover, agroforests play an important role for the delivery of pollination services as they can provide diverse food resources and nesting sites and, therefore, enhance the species richness of bees (Hass et al. 2018; Schrader et al. 2018, this issue) and arthropod decomposers that break down plant materials (Magcale-Macandog et al. 2018, this issue) potentially providing nutrients to adjacent rice fields. Additionally, plants are visited by more diverse bee species communities in structurally diverse "polyculture" than in "monoculture" rice fields, possibly leading to more stable pollination services in heterogeneous agro-ecosystems (Hass et al. 2018, while on the other hand pollination may suffer from invasive *Varroa* mites which affect honeybees, Beaurepaire et al. 2015). Efforts to achieve sustainability in rice landscapes might focus on the interchange of species between rice paddies and adjacent wild areas, including consideration of rice paddies as habitat for endangered wildlife (Horgan et al. 2018, this issue). Moreover, not only the composition but also the configuration of rice landscapes together with regional environmental drivers (i.e. climatic conditions and land use intensity) is known to affect rice-arthropod communities and their potential for natural pest regulation (Dominik et al. 2017). Increasing the heterogeneity of the farmland leads to pest reduction in rice, while maintaining smaller rice patches and enhancing the connectivity of rice bunds benefit the natural enemies of pests (Dominik et al. 2018). Landscape management to improve biodiversity and biological pest control in rice agro-ecosystems should promote a diversity of habitat types and focus on manipulating the configuration of rice fields, maintaining smaller rice patches and greater connectivity of rice bunds (Dominik et al. 2018). Thus, policies should focus on sustainable agroecological intensification (Tscharntke et al. 2012) rather than promoting large monocultures in rice-based production systems.

Cultural services

Cultural landscapes are dynamic systems and, besides environmental drivers, are influenced by economic, social and cultural developments of societies (Rössler 2009). In general, landscapes are differently interpreted and, depending on subjective perspective, can be understood as cultural heritage, nature and production factor, or as recreation site (Kühne 2013). In LEGATO for the assessment of cultural services of rice landscapes, three land use types were differentiated (see Fig. 2 for geographical setting): (a) historic landscapes with self-sufficiency production at low yield levels (mountainous areas: VN_3, and PH_3, see Fig. 4), (b) intensive rice production in crop rotation with other crops or vegetables (VN_2, and PH_1, and (c) very intensively managed rice production with rice as the only crop (VN_1, VN_4, and PH_2).

Compared to modern agricultural schemes focusing on efficiency and productivity (in a small number of dimensions), historic (rice) landscapes are distinctively characterised by a long-term human interaction with nature (Rössler 2009). They contain characteristic elements of socio-cultural history and have intangible values for the local population that go beyond the scope of exerting pure material and existential functions.

The analysis of Cultural Services in rice landscapes in LEGATO started with taking stock of the existing values associated with nature, with a particular focus on rice cultivation. A qualitative approach was chosen to analyse and describe the perceptions of farmers in their socio-cultural and socio-economic context with a focus on three cultural ES categories: cultural identity, landscape aesthetics, and knowledge systems. We derived these three categories as composites based on the Cultural Service categories of the MA (2005) (Tekken et al. 2017).

The analysis of the local perception of landscapes was aimed to evaluate farmer's subjective preferences, and their knowledge of systemic causalities of rice field biodiversity, which is important for the implementation of EE strategies (Tekken and Settele 2014). The results of the interviews conducted showed that cultural services associated with rice landscapes were more frequently mentioned by farmers in the traditional, mountainous study regions. The analysis also confirmed synergies between the different cultural services and indicated that the level of cultural ESS perceived is negatively correlated with the state of agricultural modernisation. Cultural identity is linked to expert and tacit knowledge of traditional land management and livelihood strategies (e.g. production of organic manure, traditional medicine, taking care of buffalos, or alternative food sources based on local wild flora and fauna). Further, often aesthetic components of the landscape are closely linked to the aspects of cultural identity (spiritual rituals in mountain forests, or graveyards in rice fields). Socio-cultural and socio-economic change particularly in connection with technological progress influence the attitude towards nature: whereas in the past nature was often feared as "enemy" that needs to be "appeased" by rituals, nowadays modern means of production make nature "controllable" and "assessable".

In all study regions, socio-cultural structures and the socioeconomic situation of farmers influenced their views of landscape-related cultural services. The qualitative approach of this research provides an important contribution to the field of ecosystem service assessments, because these are the values people perceive, their individual but culturally embedded and socially shaped preferences (Tekken et al. 2017). On a more practical level, the results can help agriculturalists to develop better communication methods, e.g. to initiate adoption of sustainable practices.

Focusing on the interrelations between cultural services and the state of the landscape in a concrete setting (Ifugao rice terraces), two possible processes pervade resulting in different development scenarios. On the one hand, increasing landscape degradation leads to a decline in landscape aesthetics, spiritual values, knowledge systems and recreation. As spiritual values and knowledge systems are strongly connected to the cultural identity and heritage values, an increasing degradation might also lead to their decline. On the other hand, the change in cultural services has an impact on the state of the landscape. The trade-offs here are that with decreasing traditional and local knowledge as well as

Fig. 4 LEGATO landscape "Batad" within region "PH_3 Ifugao" (compare Fig. 2). These amphitheatre-like terraces are part of the UNESCO world heritage sites of Ifugao province, N- Luzon, Philippines (photo credits J. Settele 2012)

cultural identity and heritage values the degradation of the terraces further increases. In addition, increasing recreational use leads to more degradation, although sometimes tourism-related income can be helpful for restoring the terraces which would be a positive trade-off which might, e.g. also be linked to citizen science activities which include tourists, tourist guides and local students and farmers (Dem et al. 2018; this issue). From the policy perspective, cultural revalorisation of agricultural practices is a key recommendation for landscape conservation (Tilliger et al. 2015).

Valuation

LEGATO has developed valuations of ESS through non-monetary and monetary methods (Spangenberg and Settele 2016). The most meaningful components to be calculated in monetary terms refer to financial flows such as (potential) damage costs (e.g. due to production losses), management/repair costs (regulation), and avoidance costs (precautionary measures). Non-monetary costs are crucial not only for cultural services, but are associated with every land use change. For instance, the image of farming as ‘hard work for little money and low reputation’, clearly expressed by farmers in our interviews in Vietnam as well as in the Philippines, led farmers to recommend their children to look for other jobs paying their education. On the other hand, the same farmers would never give up their job as it is part of a valued, non-substitutable identity, and a condition for staying a member of the - also valued - farming community. In the Lao Cai province around Sapa (VN_3, mountainous region; see Fig. 2), local women explained that they invest 1 year for the production of a high-quality traditional outfit for their own use, spend less time for producing their husbands’ clothes and the lowest effort is put into tourist products. This shows that the value of tradition justifies higher investments of time and labour than the value of money (Spangenberg et al. 2014b). As rule of thumb, every activity, which contributes to the mobilisation and appropriation of provisioning ESS, also has a cultural value. Regulating services—if recognised—are either valued as nature’s gift or as a transcendental contribution to human well-being. Consequently, training programs and advice, which do not address the wide range of values, are bound to fail. Hence, both monetary and non-monetary values must be integrated into the implementation of ecological engineering programs. This was, e.g. obeyed in the design of the LEGATO entertainment-education episodes, which makes them quite different from information and education movies shown on many official agricultural TV programs. However, an important challenge is to mainstream such programmes into the TV stations’ regular programming. In Vietnam where LEGATO implemented the entertainment-education approach, local TV stations contributed free broadcast time, while the creative design and scientific content of these programmes required funding (Escalada et al. 2017).

Indicators

LEGATO developed a set of indicators to characterise the state of the environment and related socio-economic and cultural factors in the seven LEGATO study regions. The components of the LEGATO indicator framework can be applied to describe ecosystem structures, functions and services. The indicator derivation considered, tested and improved already existing indicators for ESF/ESS and their values, such as those of the CBD (Convention on Biological Diversity) and the SEBI (Streamlining European Biodiversity Indicators). Beyond the applicability of the existing ones, specific integrative indicators were tested for their suitability (e.g. the “Human Appropriation of Net Primary Productivity—HANPP” tested in VN_3; Li 2014). Resilience and adaptability of rice-based agricultural human-environmental systems were analysed in a case study in Ifugao (PH_3; Castonguay et al. 2016). Indicator research is conducted on intra-, trans- and superregional scales via cross-regional comparisons. The DPSIR (Driver-Pressure-State-Impact-Response) indicator scheme, popularised by the European Environment Agency (EEA), complemented by a drivers’ institutional hierarchy analysis as developed in the ALARM project (Maxim et al. 2009; Spangenberg et al. 2015a, b) was applied to illustrate the interactions of the economic and socio-cultural factors with geo-biogenic ones in shaping landscapes and ESS provision and recognition. Feedbacks from stakeholders and project partners on the indicator framework were collected during fieldwork and meetings in the LEGATO regions. These feedbacks revealed valuable insights which have been deepened by focus group discussions and stakeholder interviews conducted by regional LEGATO partners.

Further developing the conceptual framework of ecosystem service research

Based on the experiences from LEGATO (and other large research projects), the conceptual framework for ESS research and implementation was developed further, e.g. in the context of the metaphor of ecosystem service cascades (Spangenberg et al. 2014a). The ‘cascade model’ of ecosystem service generation and valuation originally presented by Haines-Young and Potschin (2010); Potschin and Haines-Young (2011) highlights the steps which link the biophysical aspects (incl. biodiversity) to human well-being, in particular for the case of marginal changes. However, it did not include human agency as a co-producer of ESS, an obviously necessary ingredient not only in farming. We modified the cascade (see Fig. 5) by including, in particular, societal processes and the role of stakeholders as the ones defining services. The inclusion allowed representing appropriation and provisioning activities and thus the link to the resulting impacts on human livelihoods. This connects the cascade logic to natural resource governance since appropriation and provisioning actions are at the center of institutional analyses of natural resource management. A further LEGATO output (Spangenberg et al. 2014b) shows how use value attribution turns biophysical ecosystem functions (ESF) into ecosystem service potentials (ESP), which—except for 'final services'—have to be mobilised to provide ESS. Once appropriated, these services generate ecosystem benefits which may be commercialised.

For the assessment of ecosystem management and landscape planning, the 'cascade' can be reversed, turning into a 'stairways'. People making efforts to improve the stock of ESS and ESF are often motivated by the benefits they expect to receive. The upwards view of the 'stairways' can be used to describe and model adaptive management, respectively adaptive governance where several players are involved. For better targeting ESS assessments towards information needs in land use decisions, we developed a stepwise, problem-oriented approach (Förster et al. 2015). This aims at (1) structuring ES information according to land use problems identified by stakeholders, (2) targeting context-specific ES information needs by decision makers, and (3) assessing relevant management options and thus reflects the co-design-based concept of LEGATO.

Outlook

LEGATO analysed the current and traditional land use, integrating partners from science and practice, in order to evaluate how natural processes could be used to their optimum extent. The applied principles, subsumed under Ecological Engineering, are low-risk and cost-effective strategies focusing on location-appropriate resource use as an alternative or complement to current agricultural practices. The development of sustainable farming strategies for smallholders and subsistence farmers should also take socio-cultural aspects into account, such as knowledge exchange on risks or opportunities regarding successful farming. The combination of traditional knowledge and experiences and the new scientific knowledge on how to use biological diversity for enhancing ecosystem services can achieve food security based on functional habitat heterogeneity.

The cultural revalorisation of especially traditional agricultural practices intends to strengthen them not only for the purpose of food provision, or as an indirect generator of

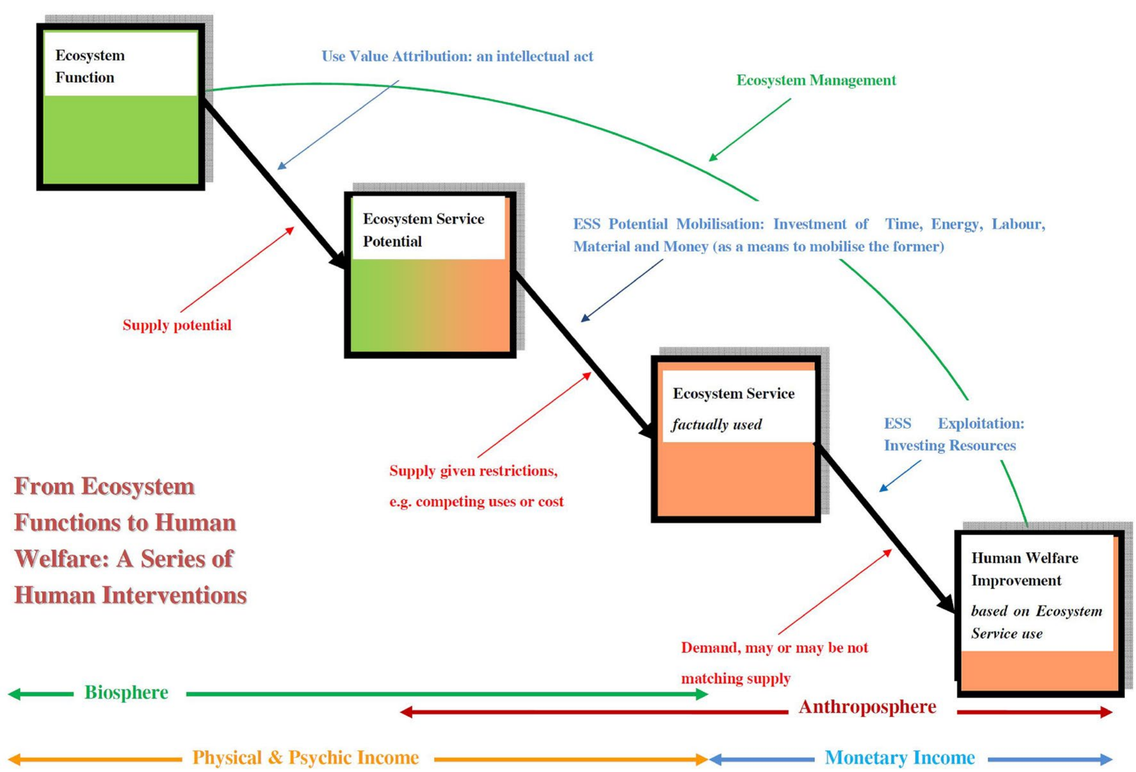

Fig. 5 The 'cascade model' of ecosystem service generation and valuation (modified after Haines-Young and Potschin 2010; Potschin and Haines-Young 2011; Spangenberg et al. 2014b)

income (e.g. through recreational activities), but also as the materialisation of a heritage that is intertwined with diverse cultural factors. The concrete means for this revalorisation are also a matter for further research, but in any case should be based on a detailed comprehension of the cultural aspects of agriculture in the study areas.

Additionally, the complex interrelations that emerge when looking at ESS provision in agricultural areas might seem to call into question the assumed linear flow from nature to services to benefits in assessment models based on economic thinking such as the initial ESS cascade (Potschin and Haines-Young 2011). Therefore, it is crucial to look at the interrelations between ESS using non-monetary evaluation approaches.

To follow-up the insights on the role of silicon in productive rice cultivation, which are of unexpectedly high scientific as well as stakeholder relevance, further research should address linkages between plant Si supply and the susceptibility of rice crops to pests and diseases under field conditions as well as the role of Si in cycling and availability of other important nutrients, like nitrogen and phosphorous. Further, it is crucial to assess and evaluate in more detail the opportunities farmers have for improving the Si supply in Si-deficient regions, such as Vietnam (see discussions on this aspect in Nguyen et al. 2018, this issue).

For the implementation of flower strips within EE programs more experimental studies are needed (see Gurr et al. 2016) to identify seed mixtures and to analyse potential interactions between different spatial scales and ecosystem services.

Another important future aim is transferring LEGATO research results and recommendations in an adapted form depending on local circumstances (see Václavík et al. 2016), which is important even within countries, like in the case of transferring information between Southern and Northern Vietnam, as well as for the planned extensions to China, Thailand, Indonesia, Taiwan, Malaysia and other countries in the region. The combination of participatory approaches, innovative communication strategies and the use of new technologies, such as social media and internet-based decision tools, will be used to spread the knowledge and to continue participatory research in different regions throughout Southeast Asia and beyond (Westphal et al. 2015).

Acknowledgements We dedicate this work to the late Gertrudo "Dong" Arida, who sadly passed away during the finalisation of LEGATO. We are really indebted to the more than 500 farmers who have wholeheartedly supported our research within their fields. We also thank the German Federal Ministry of Education and Research (BMBF) for funding the LEGATO Project (Funding Codes 01LL0917A until 01LL0917O) within the BMBF-Funding Measure "Sustainable Land Management" (http://nachhaltiges-landmanagement.de), and especially Uta von Witsch for her continuous support from the funding organisation's side. We are also indebted to Patrick VanDamme and Klaus Hubacek for critically accompanying the project.

References

Arida GS, Punzal BS, Marquez LV, Corales RG, Settele J (2016) Impact of Palaya-manan fields on conservation biological control in rice-based cropping systems. Philipp Entomol 30:85–94

Bac DK, Burkhard B, Müller F, Bao VD (2018). Modelling and mapping natural hazard regulating ecosystem services in Sapa, Lao Cai Province, Vietnam. Paddy Water Environ. 16(4) (**under review**)

Beaurepaire AL, Truong TA, Fajardo AC, Dinh TQ, Cervancia C et al (2015) Host specificity in the honeybee parasitic mite, Varroa spp. in Apis mellifera and Apis cerana. PLoS ONE 10(8):e0135103. https://doi.org/10.1371/journal.pone.0135103

Blaauw BR, Isaacs R (2014) Flower plantings increase wild bee abundance and the pollination services provided to a pollination-dependent crop. J Appl Ecol 51:890–898

Burkhard B, Müller A, Müller F, Grescho V, Anh Q, Arida G, Bustamante JV, Chien HV, Heong KL, Escalada M, Marquez L, Truong DT, Villareal S, Settele J (2015) Land cover-based ecosystem service assessment of irrigated rice cropping systems in southeast Asia: an explorative study. Ecosyst Serv 14:76–87

Castonguay AC, Burkhard B, Müller F, Horgan FG, Settele J (2016) Resilience and adaptability of rice terrace social-ecological systems: a case study of a local community's perception in Banaue, Philippines. Ecol Soc 21(2):15

Coria J, Calfucura E (2012) Ecotourism and the development of indigenous communities: the good, the bad, and the ugly. Ecol Econ 73:47–55

Dem ES, Rodríguez Labajos B, Wiemers M, Ott J, Hirneisen N, Bustamante JV, Bustamante M, Settele J (2018) Understanding the relationship between volunteers' motivations and learning outcomes of citizen science in rice ecosystems in the Northern Philippines. Paddy Water Environ https://doi.org/10.1007/s10333-018-0664-9 (**this issue**)

Dominik C, Seppelt R, Horgan FG, Marquez L, Settele J, Václavík T (2017) Regional-scale effects override the influence of fine-scale landscape heterogeneity on rice arthropod communities. Agric Ecosyst Environ 246:269–278

Dominik C, Seppelt R, Horgan F, Settele J, Václavík T (2018) Landscape composition, configuration, and trophic interactions shape arthropod communities in rice agroecosystems. J Appl Ecol. https://doi.org/10.1111/1365-2664.13226

Escalada MM, Heong KL, Settele J (2017) Entertainment education for ecological engineering. In: Liniger HP, Studer M, Moll P, Zander U (eds) Making sense of research for sustainable land management. Centre for development and environment (CDE), University of Bern, Switzerland and Helmholtz-Centre for Environ-mental Research GmbH-UFZ, Leipzig, Germany. pp 267–270. https://www.wocat.net/makingsense. Accessed 23 May 2018

Förster J, Barkmann J, Fricke R, Hotes S, Kleyer M, Kobbe S, Kübler D, Rumbaur C, Siegmund-Schultze M, Seppelt R, Settele J, Spangenberg JH, Tekken V, Vaclavik T, Wittmer H (2015) Assessing ecosystem services for informing land use decisions: a problem-oriented approach. Ecol Soc 20(3):31

Fried O, Kühn I, Schrader J, Sinh NV, Bergmeier E (2017) Plant diversity and community composition of rice agroecosystems in Vietnam and the Philippines. Phytocoenologia 47:49–66. https://doi.org/10.1127/phyto/2017/0123

Fried O, Kühn I, Schrader J, Sinh NV, Bergmeier E (2018) Plant diversity and composition of rice field bunds in Southeast Asia. Paddy Water Environ. https://doi.org/10.1007/s10333-018-0657-8. (this issue)

Godfray HCJ, Garnett T (2014) Food security and sustainable intensification. In: Philosophical transactions of the Royal Society B: biological sciences, p 369

Görg C, Spangenberg JH, Tekken V, Burkhard B, Truong Dao Thanh, Escalada M, Heong KL, Arida G, Bustamante JV, Van Chien Ho, Klotzbuecher T, Marquez L, Marxen A, Manh Nguyen Hung, Van Sinh Nguyen, Villareal S, Settele J (2014) Engaging local knowledge in biodiversity research: experiences from large inter- and transdisciplinary projects. Interdiscip Sci Rev 39:323–341

Guntzer F, Keller C, Meunier J-D (2012) Benefits of plant silicon for crops: a review. Agron Sustain Dev 32:201–213

Gurr GM, Wratten SD, Altieri MA (2003) Ecological engineering for pest management: advances in habitat manipulation for arthropods. CABI. p xi + 232

Gurr GM, Lu Z, Zheng X, Xu H, Zhu P, Chen G, Yao X, Cheng J, Zhu Z, Catindig JL, Villareal S, Van Chien H, Cuong le Q, Channoo C, Chengwattana N, Lan LP, Hai le H, Chaiwong J, Nicol HI, Perovic DJ, Wratten SD, Heong KL (2016) Multi-country evidence that crop diversification promotes ecological intensification of agriculture. Nat Plants 2:16014. https://doi.org/10.1038/nplants.2016.14 **(PMID: 27249349)**

Haines-Young R, Potschin M (2010) The links between biodiversity, ecosystem services and human well-being. In: Raffaelli D, Frid C (eds) Ecosystem ecology: a new synthesis. Cambridge University Press, Cambridge, pp 110–139

Hass AL, Liese B, Heong KL, Settele J, Tscharntke T, Westphal C (2018) Plant-pollinator interactions and bee functional diversity are driven by agroforests in rice-dominated landscapes. Agric Ecosyst Environ 253:140–147

Heong KL, Wong L, de los Reyes JH (2015) Addressing Planthopper threats to asian rice farming and food security: fixing insecticide misuse. In: Heong KL, Cheng J, Escalada MM (eds) Rice planthoppers: ecology, management, socio economics and policy. Zhejiang University Press and Springer, Hangzhou, pp 69–80

Horgan FG, Ramal AF, Bernal CC, Villegas JM, Stuart AM, Almazan MLP (2016) Applying ecological engineering for sustainable and resilient rice production systems. Proc Food Sci 6:7–15

Horgan FG, Ramal AF, Villegas JM, Jamoralin A, Bernal CC, Perez MO, Pasang JM, Naredo AI, Almazan ML (2017a) Effects of bund crops and insecticide treatments on arthropod diversity and herbivore regulation in tropical rice fields. J Appl Entomol 141:587–599. https://doi.org/10.1111/jen.12383

Horgan FG, Ramal AF, Villegas JM, Almazan MLP, Bernal CC, Jamoralin A, Pasang JM, Orboc G, Agreda V, Arroyo C (2017b) Ecological engineering with high diversity vegetation patches enhances bird activity and ecosystem services in Philippine rice fields. Reg Environ Change 17:1355–1367

Horgan FG, Kudavidanage EP, Weragodaarachchi A, Ramp D (2018) Traditional 'maavee' rice production in Sri Lanka: environmental, economic and social pressures revealed through stakeholder interviews. Paddy Water Environ. https://doi.org/10.1007/s10333-017-0604-0 **(this issue)**

Keune H, Subramanian SM, Payyappallimana U, Ahmad S, Rahman M, Mofizur A, Nurul M, Sebesvari Z, Spangenberg JH, Morand S, Kretsch C, Martens P, Wittmer H (2017) Biodiversity, ecosystems and human health: a complicated but important science policy challenge. In: Morand S, Lajaunie C, Satrawaha R (eds) Biodiversity conservation in Southeast Asia: challenges in a changing environment. Routledge/Eartscan, London, pp 250–280

Klotzbücher T, Marxen A, Vetterlein D, Schneiker J, Türke M, Sinh NV, Manh NH, Chien HV, Marquez L, Villareal S, Bustamante JV, Jahn R (2015a) Plant-available silicon in paddy soils as a key factor for sustainable rice production in Southeast Asia. Basic Appl Ecol 16:665–673

Klotzbücher T, Leuther F, Marxen A, Vetterlein D, Horgan F, Jahn R (2015b) Forms and fluxes of potential plant-available silicon in irrigated lowland rice production (Laguna, the Philippines). Plant Soil 393:177–191

Klotzbücher T, Marxen A, Jahn R, Vetterlein D (2016) Silicon cycle in rice paddy fields: insights provided by relations between silicon forms in topsoils and plant silicon uptake. Nutr Cycl Agroecosyst 105:157–168

Klotzbücher A, Klotzbücher T, Jahn R, Xuan LD, Cuong LC, Chien HV, Hinrichs M, Sann C, Vetterlein D (2018a) Effects of Si fertilization on Si in soil solution, Si uptake by rice, and resistance of rice to biotic stresses in Southern Vietnam. Paddy Water Environ. https://doi.org/10.1007/s10333-017-0610-2 **(this issue)**

Klotzbücher T, Klotzbücher A, Kaiser K, Vetterlein D, Jahn R (2018b) Mikutta R (2018b) Variable silicon accumulation in plants affects terrestrial carbon cycling by controlling lignin synthesis. Glob Change Biol 24:e183–e189. https://doi.org/10.1111/gcb.13845

Kühne O (2013) Landschaftstheorie und Landschaftspraxis. Eine Einführung aus sozialkonstruktivistischer Perspektive. Springer, Wiesbaden

Langerwisch F, Václavík T, von Bloh W, Vetter T, Thonicke K (2018) Combined effects of climate and land-use change on the provision of ecosystem services in rice agro-ecosystems. Environ Res Lett 13(1):015003

Li S (2014) Application of the human appropriation of net primary production (HANPP) to rice agriculture in the Sa Pa Region, Lao Cai, Vietnam. In: Master thesis. Kiel University, Kiel, p 77

Lin YP, Settele J, Petway JR (2018) Ecoregional and archetypical considerations for national responses to food security under climate change. Environments 5:32

MA/Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: synthesis. Island Press, Washington

Magcale-Macandog DB, Manlubatan MBT, Javier JM, Edrial JD, Mago KS, De Luna JEI, Nayoos J, Porcioncula RP (2018) Leaf litter decomposition and diversity of arthropod decomposers in tropical Muyong forest in Banaue, Philippines. Paddy Water Environ. https://doi.org/10.1007/s10333-017-0624-9 **(this issue)**

Marxen A, Klotzbücher T, Jahn R, Kaiser K, Nguyen VS, Schmidt A, Schädler M, Vetterlein D (2016) Interaction between silicon cycling and straw decomposition in a silicon deficient rice production system. Plant Soil 398:153–163

Maxim L, Spangenberg JH, O'Connor M (2009) The DPSIR framework for biodiversity assessment. Ecol Econ 69(1):12–23

Mitsch WJ (2012) What is ecological engineering? Ecol Eng 45:5–12

Nguyen SV, Nguyen MH, Klotzbücher A, Vetterlein D, Klotzbücher T, Jahn R, Schneiker J, Türke M, Fried O, Bergmeier E, Sattler C, Settele J (2018) From science to application: field demonstrations to enhance sustainable rice production in the North of Vietnam: lessons from the LEGATO project. Paddy Water Environ. https://doi.org/10.1007/s10333-018-0644-0 **(this issue)**

Ott J (2015) Libellen in Reisfeldern Asiens – nur bunte Dekoration oder ein wichtiger Bestandteil des Okosystems? In: Diehl P, Imhoff A, Möller L (eds.) Wissensgesellschaft Pfalz: 90 Jahre Pfälzische Gesellschaft zur Förderung der Wissenschaften. Heidelberg, pp 327–334

Panteleit J, Horgan FG, Türke M, Schmidt A, Schädler M, Bacht M, Brandl R, Hotes S (2018) Effects of detritivorous invertebrates on the decomposition of rice straw: evidence from a microcosm experiment. Paddy Water Environ. https://doi.org/10.1007/s10333-017-0625-8 **(this issue)**

Potschin MB, Haines-Young RH (2011) Ecosystem services: exploring a geographical perspective. Prog Phys Geogr 35:575–594

Rössler M (2009) Kulturlandschaften im Rahmen der UNESCO-Welterbekonvention. Welterbe-Manual. Handbuch zur Umsetzung der Welterbekonvention in Deutschland, Luxemburg, Österreich und der Schweiz. D. UNESCO-Kommission. Bonn, p 354

Sann C, Westphal C, Theodorou P, Heong KL, Villareal S, Settele J, Vidal S (2018a) Hopper parasitoids do not significantly benefit from non-crop habitats in rice production landscapes. Agric Ecosyst Environ 254:224–232

Sann C, Wemheuer F, Beaurepaire A, Daniel R, Erler S, Vidal S (2018b) Preliminary investigation of species diversity of rice hopper parasitoids in Southeast Asia. Insects 9(1):19

Sattler C, Schrader J, Farkas VM, Settele J, Franzén M (2018) Pesticide diversity in rice growing areas of Northern Vietnam. Paddy Water Environ. https://doi.org/10.1007/s10333-018-0637-z **(this issue)**

Schmidt A, Auge H, Brandl R, Heong KL, Hotes S, Settele J, Villareal S, Schädler M (2015a) Small-scale variability in the contribution of invertebrates to litter decomposition in tropical rice fields. Basic Appl Ecol 16:674–680

Schmidt A, John K, Arida G, Auge H, Brandl R, Horgan FG, Hotes S, Marques L, Radermacher N, Settele J, Wolters V, Schädler M (2015b) Effects of residue management on decomposition in irrigated rice fields are not related to changes in the decomposer community. PLoS ONE 10(7):e0134402

Schmidt A, John K, Auge H, Brandl R, Horgan FG, Settele J, Zaitsev AS, Wolters V, Schädler M (2016) Compensatory mechanisms of litter decomposition under alternating moisture regimes in tropical rice fields. Appl Soil Ecol 107:79–90

Schneiker J, Weisser WW, Settele J, Sinh VN, Bustamante JV, Marquez L, Villareal S, Arida G, Chien HV, Heong KL, Türke M (2016) Is there hope for sustainable management of golden apple snails, a major invasive pest in irrigated rice? NJAS Wageningen J Life Sci 79:11–21

Schrader J, Franzén M, Sattler C, Ferderer P, Westphal C (2018) Woody habitats promote pollinators and complexity of plant: pollinator interactions in homegardens located in rice terraces of the Philippine Cordilleras. Paddy Water Environ. https://doi.org/10.1007/s1033.3-017-0612-0 **(this issue)**

Settele J (2010) Biodiversity and our future: new alliances for new policies? Gaia-Ecol Perspect Sci Soc 19:161

Settele J, Spangenberg JH, Heong KL, Burkhard B, Bustamante JV, Cabbigat J, Chien HV, Escalada M, Grescho V, Hai LH, Harpke A, Horgan F, Hotes S, Jahn R, Kühn I, Marquez L, Schädler M, Tekken V, Vetterlein D, Villareal S, Westphal C, Wiemers M (2015) Agricultural landscapes and ecosystem services in South-East Asia: the LEGATO-project. Basic Appl Ecol 16:661–664

Settele J, Spangenberg JH, Heong KL, Kühn I, Klotz S, Bustamante JV, Cabbigat J, Canh LX, Catindig JLA, Chien HV, Cuong LQ, Escalada M, Grescho V, Grossmann S, Hai LH, Harpke A, Horgan FG, Jahn R, Klotzbücher T, Marquez L, Klotzbücher A, Ott J, Rodriguez-Labajos B, Sattler C, Schweiger O, Seppelt R, Václavík T, Vetterlein D, Villareal S, Westphal C, Wiemers M (2018) Rice Ecosystem Services in South-East Asia: the LEGATO project, its approaches and main results with a focus on biocontrol services. In: Schröter M, Bonn A, Klotz S, Seppelt R, Baessler C (eds) Atlas of ecosystem services: drivers, risks, and societal responses. Springer, New York **(in press)**

Siew TF, Aenis T, Spangenberg JH, Nauditt A, Döll P, Frank S, Ribbe L, Rodriguez-Labajos B, Rumbaur C, Settele J, Wang J (2016) Transdisciplinary research in support of land and water management in China and Southeast Asia: evaluation of four research projects. Sustain Sci 11:813–829

Spangenberg JH, Settele J (2016) Value pluralism and economic valuation: defendable if well done. Ecosyst Serv 18:100–109

Spangenberg JH, von Haaren C, Settele J (2014a) The ecosystem service cascade: further developing the metaphor. Integrating societal processes to accommodate social processes and planning, and the case of bioenergy. Ecol Econ 104:22–32

Spangenberg JH, Görg C, Truong DT, Tekken V, Bustamante JV, Settele J (2014b) Provision of ecosystem services is determined by human agency, not ecosystem functions. Four case studies. Int J Biodivers Sci Ecosyst Serv Manag. 10(1):40–53

Spangenberg JH, Douguet J-M, Settele J, Heong KL (2015a) Escaping the Lock-In of Continuous Insecticide Spraying in Rice. Developing an integrated ecological and socio-political DPSIR analysis. Ecol Model 295:188–195

Spangenberg JH, Görg C, Settele J (2015b) Stakeholder involvement in ESS research and governance: between conceptual ambition and practical experiences: risks, challenges and tested tools. Ecosyst Serv 16:201–211

Spangenberg JH, Beaurepaire AL, Bergmeier E, Burkhard B, Ho Van Chien, Le Quoc Cuongh, Görg C, Grescho V, Le Huu Hai, Heong KL, Horgan FG, Hotes S, Klotzbücher A, Klotzbücher T, Kühn I, Langerwisch F, Marion G, Moritz RFA, Quynh Anh Nguyen, Ott J, Sann C, Sattler C, Schädler M, Schmidt A, Tekken V, Truong Dao Thanh, Thonicke K, Türke M, Václavík T, Vetterlein D, Westphal C, Wiemers M, Settele J (2018a) The LEGATO cross-disciplinary integrated ecosystem service research framework. An example of integrating research results from the analysis of global change impacts and the social, cultural and economic system dynamics of irrigated rice production. Paddy Water Environ. https://doi.org/10.1007/s10333-017-0628-5(**this issue**)

Spangenberg JH, Heong KL, Klotzbücher A, Klotzbücher T, Nguyen Quynh Anh, Tekken V, Thanh Truong Dao, Türke M, Settele J (2018b) Doing what with whom? Stakeholder analysis in a large transdisciplinary research project in South-East Asia. Paddy Water Environ. https://doi.org/10.1007/s10333-018-0634-2 **(this issue)**

Stallman HR (2011) Ecosystem services in agriculture: determining suitability for provision by collective management. Ecol Econ 71:131–139

Tekken V, Settele J (2014) Instrumente zur nachhaltigen Agrarlandschafts-Optimierung: Ecological Engineering als Ansatz zur Konstruktion nachhaltiger Agrarlandschaften in Reisanbaugebieten Südost-Asiens. In: Hartung G, Kirchhoff T (eds) Welche Natur brauchen wir?. Anthropologische Dimensionen des Umgangs mit Natur, Freiburg, Alber, pp 173–186

Tekken V, Spangenberg JH, Burkhard B, Escalada M, Stoll-Kleemann S, Truong Dao Thanh, Settele J (2017) "Things are different now": farmer perceptions of cultural ecosystem services of traditional rice landscapes in Vietnam and the Philippines. Ecosyst Serv 25:153–166

Tilliger B, Rodríguez-Labajos B, Bustamante JV, Settele J (2015) Disentangling values in the interrelations between cultural ecosystem services and landscape conservation: a case study of the Ifugao Rice Terraces in the Philippines. Land 4:888–913

Truong DT, Anh NTQ, Anh NTN, Ly DKK, Spangenberg JH, Settele J, Tekken V, Rodriguez-Labajos B (2016) Policy analysis approaches in implementing the ecological engineering in vietnam: experiences from LEGATO: an interdisciplinary project. VNU J Sci Policy Manag Stud 32(1):49–67

Tscharntke T, Clough Y, Wanger TC, Jackson L, Motzke I, Perfecto I, Vandermeer J, Whitbread A (2012) Global food security, biodiversity conservation and the future of agricultural intensification. Biol Cons 151:53–59

Tschumi M, Albrecht M, Entling MH, Jacot K (2015) High effectiveness of tailored flower strips in reducing pests and crop plant damage. Proc R Soc B 282:20151369. https://doi.org/10.1098/rspb.2015.1369

Türke M, Schmidt A, Schädler M, Hotes S, Weisser WW (2018) Are invasive apple snails important neglected decomposers of rice straw in paddy fields? Biol Agric Hortic. https://doi.org/10.1080/01448765.2018.1450161

Václavík T, Lautenbach S, Kuemmerle T, Seppelt R (2013) Mapping global land system archetypes. Glob Environ Change 23:1637–1647

Václavík T, Langerwisch F, Cotter M, Fick J, Häuser I, Hotes S, Kamp J, Settele J, Spangenberg JH, Seppelt R (2016) Investigating potential transferability of place-based research in land system science. Environ Res Lett 11:095002

Vu Q, Ramal AF, Villegas JM, Jamoralin A, Bernal CC, Pasang JM, Almazan MLP, Ramp D, Settele J, Horgan FG (2018) Enhancing parasitism of insect herbivores through diversification of habitat on Philippine rice farms. Paddy Water Environ. https://doi.org/10.1007/s10333-018-0662-y. (**this issue**)

Westphal C, Vidal S, Horgan FG, Gurr GM, Escalada M, Chien HV, Tscharntke T, Heong KL, Settele J (2015) Promoting multiple ecosystem services with flower strips and participatory approaches in rice production landscapes. Basic Appl Ecol 16:681–689

Affiliations

Josef Settele[1,2,3] · Kong Luen Heong[4] · Ingolf Kühn[1,5,3] · Stefan Klotz[1,3] · Joachim H. Spangenberg[1,6] · Gertrudo Arida[7] · Alexis Beaurepaire[5] · Silke Beck[8] · Erwin Bergmeier[9] · Benjamin Burkhard[10,11,12] · Roland Brandl[13] · Jesus Victor Bustamante[14] · Adam Butler[15] · Jimmy Cabbigat[14] · Xuan Canh Le[16,17] · Josie Lynn A. Catindig[18] · Van Chien Ho[19] · Quoc Cuong Le[19] · Kinh Bac Dang[20,21] · Monina Escalada[22] · Christophe Dominik[8] · Markus Franzén[1,23] · Oliver Fried[9] · Christoph Görg[8,24] · Volker Grescho[1,25,3] · Sabine Grossmann[1] · Geoff M. Gurr[26,27] · Buyung A. R. Hadi[18] · Huu Hai Le[28] · Alexander Harpke[1] · Annika L. Hass[29] · Norbert Hirneisen[30] · Finbarr G. Horgan[31,32] · Stefan Hotes[13,2] · Yuzuru Isoda[33] · Reinhold Jahn[34] · Helen Kettle[15] · Anika Klotzbücher[1,34] · Thimo Klotzbücher[34] · Fanny Langerwisch[35] · Wai-Hong Loke[36] · Yu-Pin Lin[37] · Zhongxian Lu[38] · Keng-Yeang Lum[36] · Damasa B. Magcale-Macandog[2] · Glenn Marion[15] · Leonardo Marquez[7] · Felix Müller[10] · Hung Manh Nguyen[16] · Quynh Anh Nguyen[39] · Van Sinh Nguyen[16,17] · Jürgen Ott[1,40] · Lyubomir Penev[41,42] · Hong Thai Pham[17,43] · Nico Radermacher[44] · Beatriz Rodriguez-Labajos[45] · Christina Sann[46] · Cornelia Sattler[1] · Martin Schädler[1,3] · Stefan Scheu[44] · Anja Schmidt[1] · Julian Schrader[29,47] · Oliver Schweiger[1] · Ralf Seppelt[8,3] · Kukiat Soitong[48] · Pavel Stoev[41,49] · Susanne Stoll-Kleemann[50] · Vera Tekken[50,51] · Kirsten Thonicke[35] · Bianca Tilliger[45] · Kai Tobias[52] · Y. Andi Trisyono[53] · Thanh Truong Dao[39] · Teja Tscharntke[29] · Quang Tuan Le[16] · Manfred Türke[54,3,55] · Tomáš Václavík[8,56] · Doris Vetterlein[1,34] · Sylvia 'Bong' Villareal[18] · Kim Chi Vu[57] · Quynh Vu[1,12,58] · Wolfgang W. Weisser[54] · Catrin Westphal[29] · Zengrong Zhu[4] · Martin Wiemers[1]

[1] UFZ - Helmholtz Centre for Environmental Research, Theodor-Lieser-Str. 4, 06120 Halle (Saale), Germany

[2] Institute of Biological Sciences, College of Arts and Sciences, University of the Philippines, Los Baños, College, Los Baños 4031, Laguna, Philippines

[3] German Centre for Integrative Biodiversity Research (iDiv), Halle-Jena-Leipzig, Deutscher Platz 5e, 04103 Leipzig, Germany

[4] Institute of Insect Sciences, Zhejiang University, Hangzhou 310058, China

[5] Institute of Biology, Martin Luther University Halle-Wittenberg, Hoher Weg 4, 06099 Halle (Saale), Germany

[6] Sustainable Europe Research Institute SERI Germany e.V., Vorsterstr. 97-99, 51103 Cologne, Germany

[7] Crop Protection Division, Maligaya, Science City of Muñoz, Philippine Rice Research Institute, 3119 Nueva Ecija, Philippines

[8] UFZ - Helmholtz Centre for Environmental Research, Permoserstr. 15, 04318 Leipzig, Germany

[9] Albrecht-von-Haller-Institute of Plant Sciences, Georg-August-University Göttingen, Untere Karspüle 2, 37073 Göttingen, Germany

[10] Institute for Natural Resource Conservation, Kiel University, Olshausenstraße 40, 24098 Kiel, Germany

[11] Institute of Physical Geography and Landscape Ecology, Leibniz Universität Hannover, Schneiderberg 50, 30167 Hannover, Germany

[12] Leibniz Centre for Agricultural Landscape Research ZALF, Eberswalder Str. 84, 15374 Müncheberg, Germany

[13] Department of Ecology, Animal Ecology, Faculty of Biology, Philipps-Universität Marburg, Karl-von-Frisch Strasse 8, 35043 Marburg, Germany

[14] LEGATO Office, 3601 Banaue, Ifugao, Philippines

[15] Biomathematics and Statistics Scotland, James Clerk Maxwell Building, Peter Guthrie Tait Road, Edinburgh EH9 3FD, UK

[16] Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Nghia Do, Cau Giay, Hanoi, Vietnam

[17] Graduate University of Science and Technology, Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Nghia Do, Cau Giay, Hanoi, Vietnam

[18] Crop and Environmental Sciences Division, IRRI - International Rice Research Institute, DAPO 7777, Los Banos, Metro Manila, Philippines

[19] Southern Regional Plant Protection Center, Long Dinh, Chau Thanh, Tien Giang, Vietnam

[20] Department of Ecosystem Management, Institute for Natural Resource Conservation, Kiel University, Olshausenstraße 40, 24098 Kiel, Germany

[21] Faculty of Geography, VNU University of Science, 334 Nguyen Trai, Thanh Xuan, Hanoi, Vietnam

[22] Department of Development Communication, Visayas State University, 6521 Visca, Baybay, Leyte, Philippines

[23] Department of Biology and Environmental Science, Center for Ecology and Evolution in Microbial Model Systems, EEMiS, Linnaeus University, 39182 Kalmar, Sweden

[24] Institute of Social Ecology, University of Natural Resources and Life Sciences Vienna, Schottenfeldgasse 29, 1070 Vienna, Austria

[25] OLANIS GmbH, Pittlerstraße 33, 04159 Leipzig, Germany

[26] Institute of Applied Ecology, Fujian Agriculture and Forestry University, Fuzhou, China

[27] Graham Centre, Charles Sturt University, Orange, NSW 2800, Australia

[28] Tien Giang University, Mỹ Tho, Vietnam

[29] Agroecology, Department of Crop Sciences, University of Goettingen, Grisebachstr. 6, 37077 Göttingen, Germany

[30] Science and Communication, von-Müllenark-Str. 19, 53179 Bonn, Germany

[31] University of Technology Sydney, 15 Broadway, Ultimo, Sydney, NSW 2007, Australia

[32] Tropical Ecosystems Research Network, 30C Nirondha, Temple Road, Piliyandala, Sri Lanka

[33] Graduate School of Science, Tohoku University, Aoba-ku, Sendai 908-8578, Japan

[34] Soil Science and Soil Protection, Martin Luther University Halle-Wittenberg, Von-Seckendorff-Platz 3, 06120 Halle (Saale), Germany

[35] Research Domain for Earth System Analysis, Potsdam Institute for Climate Impact Research (PIK), Telegraphenberg A62, 14473 Potsdam, Germany

[36] CABI Southeast and East Asia, Kuala Lumpur, Malaysia

[37] Department of Bioenvironmental Systems Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd, Taipei 10617, Taiwan, ROC

[38] State Key Laboratory Breeding Base for Zhejiang Sustainable Pest and Disease Control, Institute of Plant Protection and Microbiology, Zhejiang Academy of Agriculture Sciences, Hangzhou, China

[39] Institute of Policy and Management (IPAM), Faculty of Management Science, VNU - The University of Social Sciences and Humanities, No.336, Nguyen Trai Street, Thanh Xuan Dist, Hanoi, Vietnam

[40] L.U.P.O. GmbH, Friedhofstr. 28, 67705 Trippstadt, Germany

[41] Pensoft Publishers Ltd, Geo Milev Str. 13a, 1111 Sofia, Bulgaria

[42] Institute of Biodiversity and Ecosystem Services, Bulgarian Academy of Sciences, Sofia, Bulgaria

[43] Vietnam National Museum of Nature (VNMN), Vietnam Academy of Science and Technology (VAST), 18 Hoang Quoc Viet St, Cau Giay, Hanoi, Vietnam

[44] J.F.-Blumenbach-Institute of Zoology and Anthropology, Georg-August-University Göttingen, Untere Karspüle 2, 37073 Göttingen, Germany

[45] Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona (UAB), Edifici Z, Bellaterra, 08193 Cerdanyola del Vallès, Barcelona, Spain

[46] Department of Crop Sciences/Agricultural Entomology, Georg-August-University Göttingen, Grisebachstrasse 6, 37077 Göttingen, Germany

[47] Department of Biodiversity, Macroecology and Biogeography, University of Goettingen, 37077 Goettingen, Germany

[48] Rice Department, Jatujak, Bangkok, Thailand

[49] National Museum of Natural History, Bulgarian Academy of Sciences, Sofia, Bulgaria

[50] Department Sustainability Science and Applied Geography, University of Greifswald, Friedrich-Ludwig-Jahn-Str. 16, 17489 Greifswald, Germany

[51] Leibniz Institute for Agricultural Engineering and Bioeconomy, Max-Eyth-Allee 100, 14469 Potsdam, Germany

[52] Department of Landscape and Open Space Development, Faculty of Spatial and Environmental Planning, Technical University of Kaiserslautern, Pfaffenbergstraße 95, 76763 Kaiserslautern, Germany

[53] Department of Crop Protection, Faculty of Agriculture, University of Gadjah Mada, Yogyakarta 55281, Indonesia

[54] Department of Ecology and Ecosystem Management, Technical University Munich, Hans-Carl-von-Carlowitz-Platz 2, 85354 Freising, Germany

[55] Institute for Biology, Leipzig University, Johannisallee 21, 04103 Leipzig, Germany

[56] Department of Ecology and Environmental Sciences, Faculty of Science, Palacký University Olomouc, Šlechtitelů 27, Olomouc 78371, Czech Republic

[57] VNU – Institute of Vietnamese Studies and Development Science (VNU-IVIDES), Vietnam National University Hanoi, 336 Nguyen Trai, Thanh Xuan, Hanoi, Vietnam

[58] Cuulong Delta Rice Research Institute, Tan Thanh, Thoi Lai District, Can Tho, Vietnam