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Escaping the lock-in of continuous insecticide spraying in rice: Developing an integrated ecological and socio-political DPSIR analysis

J.H. Spangenberg[a,*], J.-M. Douguet[b], J. Settele[c], K.L. Heong[d]

[a] Helmholtz Centre for Environmental Research – UFZ, Department of Community Ecology, Vorsterstr. 97, 51103 Cologne, Germany
[b] University of Versailles Saint-Quentin-en-Yvelines, REEDS Institute, Bergerie Nationale, Rambouillet, France
[c] Helmholtz Centre for Environmental Research – UFZ, Department of Community Ecology, Theodor-Lieser-Str. 4, 06120 Halle, Germany
[d] International Rice Research Institute – IRRI, Los Baños, Philippines

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ABSTRACT

A narrow perception of causality chains can be counterproductive and self-defeating, as the case of pesticide use in Asian rice production shows. Using the Driving Forces – Pressures – State – Impact – Response (DPSIR) scheme developed by EEA and Eurostat we analyse the logic inherent to the application of insecticides. Its underlying biology-to-society perspective considers insects as the initial Pressure, spraying insecticides as adequate Response and yield protection as result.

This view is apparently supported by positive results in the early growth phase, but this short term success is paid for by increased system sensitivity, possibly leading to severe damages in the later stages when a seemingly similar situation is indeed very different. This is due to the complementary but ignored society-to-biology loop: insecticide spraying leads to biocontrol loss enhancing vulnerability.

Once the system has gone through both loops, the State of the system has changed, enhancing its sensitivity to planthopper infestations. The changed State leads to unexpected Impacts – in particular, the standard Response is no longer capable of reducing the Drivers (the numbers of planthoppers) as expected. This does not become obvious, however, before a new pressure arises and cannot be understood inside the standard management loop but requires combining it with the society-to-biology loop.

A double-DPSIR scheme is suggested as a heuristic device, and as a communication tool conveying the message in a simplified way. It shows that the Responses of one loop are the Drivers of the other, leading to different conclusions based on different pre-analytical visions.

1. Introduction: the rice planthopper challenge

Throughout South-East Asia, every year significant losses of rice harvest occur due to infestations by planthoppers; affected areas suffer from significant to total losses of harvest. While not necessarily taking place in the same place every year, they are now a wide-spread phenomenon in Vietnam, Thailand, Indonesia and Southern China, with significant impacts on regional food production (Heong et al., 2013; Gurr et al., 2011a,b; Way and Heong, 1994). In the past, the Brown Planthopper (BPH; *Nilaparvata lugens*) and the White-Backed Planthopper (WBPH; *Sogatella furcifera*) were the most relevant planthopers causing such damages. Most planthoppers (and all those which are regarded as pests) are described by ecologists as r-strategists (rapidly reproducing organisms, short generations – i.e. fast development and high number of offspring), of which many (especially the BPH) are monophagous (feeding exclusively on one plant species), and are adapted to be successful in ephemeral (i.e. only short-lived) environments that undergo perturbations (Heong, 2009). Insecticide spraying often increases the rice crop's vulnerability to such pests, as they indiscriminately destroy natural enemies and the ecosystem services they provide (Gurr, 2009; Gurr et al., 2011a, 2011b). In planthopper destroyed crops the patterns of damage often coincide with the patterns of insect spraying in the early crop stages (Heong, 2009).

The usual reaction to hopper infestation is – in particular in intensive wet rice agriculture such as in central Thailand, Vietnam and parts of China – to intensify insecticide spraying to combat the hoppers (Escalada and Heong, 2004). It is based on a mental

Abbreviations: DPSIR, Driving Forces – Pressures – State – Impact – Response; BPH, the Brown Planthopper *Nilaparvata lugens*; WBPH, the White-Backed Planthopper *Sogatella furcifera*; ESF, ecosystem function; ESP, ecosystem service potential; ESS, ecosystem service.

* Corresponding author. Tel.: +49 221 2168 9.
E-mail addresses: Joachim.Spangenberg@ufz.de, Joachim.Spangenberg@gmail.com (J.H. Spangenberg), jean-marc.douguet@reeds.uvsq.fr (J.-M. Douguet), Josef.Settele@ufz.de (J. Settele), kl.heong@gmail.com (K.L. Heong).

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0304-3800/

model which associates every infestation with significant harvest losses and conceives spraying insecticides as the first-best solution (Escalada and Heong, 2012). However, this strategy does not reliably work in the case of acute infestation, nor does it prevent future damages, resulting from direct feeding and infections by virus diseases the hoppers carry. However, although the method of choice seems to be of limited effectiveness, so far rather an intensification of spraying than testing alternative means of reducing hopper-induced losses has been observed (Huan et al., 2005). Insecticide spraying has become a behavioural routine, applied prophylactically, and if not effective, frequency and dosage are increased; the next escalation step is mixing several insecticides (Escalada and Heong, 2012).

An alternative offered by ecological engineering (Gurr et al., 2012) is based on a different mental model, emphasising not the suppression but the deliberate exploitation of existing biological structures and mechanisms, such as food chains (Gurr et al., 2011a,b). In many of its recommendations similar to the rapidly spreading System of Rice Intensification SRI (Glover, 2011; Basu and Leeuwis, 2012; Burney et al., 2010; Satyanarayana et al., 2007) it includes withholding insecticide applications in the first 40 days after sowing to avoid disturbances of the available biocontrol potential, but adds actively supporting biocontrol by planting suitable, nectar-rich plants on the paddy dykes to serve as shelter and food for biocontrol agents such as egg parasitoids of the genus *Anagrus*, the mirid egg predator *Cyrtorhinus lividipennis* and the water predatory bug *Microvelia douglasi atrolineata*. The ecological engineering approach has been demonstrated to be effective in experimental fields in China, Thailand and Vietnam, demonstrating the applicability of the management concept in day-to-day practice (Escalada et al., 1999; Huan et al., 2008; Gurr, 2009; Gurr et al., 2011a,b, 2012; Lou et al., 2013; Shanker et al., 2013). Besides reducing harvest losses it is effectively reducing input costs (especially insecticides) and helps save time for other purposes such as husbandry (Escalada and Heong, 2004). Add to this the reduction of health risks for both producers and consumers, and the ecological engineering management approach should be expected to spread like wild fire – which it does not.

Why is this so? Obviously there is a problem with the feedback mechanism, preventing effective learning processes. This paper analyses the impact-to-reaction mechanisms causing this lock-in situation, i.e. the habit of answering to infestation with increasing doses of insecticide spraying as routine behaviour. It does so by using the Driving Forces – Pressures – State – Impact – Response DPSIR model developed to communicate the need for Response action arising from different impacts and their causes. We will argue that the DPSIR scheme describes a closed loop approach driven by the socio-economic system, which can be frequently observed in real-world decision making. However, it suffers from neglecting feedback mechanisms which can be described as a complementary DPSIR mechanism driven by the natural systems, and thus is blinded against "green" experience and scientific analysis. Only by integrating both cycles the lock-in can be broken and a problem solving management strategy be developed.

2. Examining the DPSIR model

2.1. The standard model

DPSIR stands for a system analysis view on environmental problems and the way society deals with them. According to its terminology, social and economic developments (Driving Forces, D) exert Pressures (P) on the environment and, as a consequence, the State (S) of the environment changes. This leads to Impacts (I) on ecosystems, human health, and society, which may elicit a societal Response (R) that feeds back on Driving Forces, on State or on Impacts (see Fig. 1 from Smeets and Weterings, 1999; Gabrielsen and Bosch, 2003). Thus, the DPSIR scheme is described as a "*causal framework for describing the interactions between society and the environment*" (EEA, 2006).

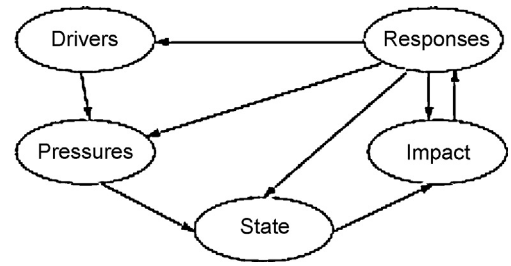

Fig. 1. The DPSIR model (Smeets and Weterings, 1999) assumes a causal chain from Driving Forces in the socio-economic system causing Pressures on the environment which affect its State and cause Impacts on society and economy. These in turn trigger Responses intended to minimise the impacts by addressing either step of the causality chain.

The DPSIR scheme can be used in a range of ways, for instance as a way of framing a problem as such (what shall be taken into account) and the questioning about it (which are the key issues the problem is linked or related to), but also as a way of choosing, structuring and mobilising indicators (defining for what, for whom and why, and from which point of view). In this paper we use it as a model of systemic relation between the DPSIR elements in order to derive adequate problem solving strategies. In a further step, the scheme as presented here would support analysing the effects of anthropogenic actions on different ecosystem services and the overall system resilience, linking the DPSIR and the ecosystem service concept, for instance as formulated in the "ecosystem service cascade" approach (Potschin and Haines-Young, 2011; Spangenberg et al., 2014b).

Since 1995, the model has been used widely by the European Environment Agency and by Eurostat, for the organisation of environmental indicators and statistics (Smeets and Weterings, 1999; Jesinghaus, 1999). The framework was applied to the issue of biodiversity by Delbaere (2003) and the EEA (2007), and specified for that purpose by Spangenberg et al. (2009) and Maxim et al. (2009). Two features of the DPSIR model have contributed to its wide use. First, it structures the measures to be taken with reference to political objectives related to the environmental management problem addressed; and second, it focuses on supposed causal relationships, in a clear way that appeals to policy actors (Smeets and Weterings, 1999; Giupponi, 2005). However, for analytical purposes, and as planning instrument, the scheme is unsatisfying. The simple causal relations assumed cannot capture the complexity of interdependencies in the real world (Smeets and Weterings, 1999; Gobin et al., 2004). Although the didactic clarity is appealing, the simplicity can be misguiding. An apparently deterministic and linear 'causal' description of environmental issues inevitably downplays the uncertainty inherent in complex environmental and socio-economic systems (Spangenberg, 2007).

To avoid the problems resulting from these shortcomings, we suggest using the DPSIR scheme not as an analytical or planning tool but as a heuristic device to structure, demonstrate and communicate observations collected independent from the DPSIR approach. Applied this way, it is a useful tool not only for structuring communication about necessary policy measures (the science–policy interface), but also to identify the strengths and weaknesses of existing plans and policies.

2.2. Definitions

A second problem to be solved before applying the scheme is that the qualities of the DPSIR scheme in terms of flexibility, general applicability, organisation of the information and as framework for communication between scientists and politicians, are counterbalanced by the fact that the applicability in very diverse situations renders the definitions of its components very generic and sometimes even incoherent. To overcome this problem, coherent definitions are needed, derived by anchoring the concept in a broader and more systematic approach to system analysis. Based on such an embedding procedure, consistent definition of the DPSIR components can be derived (Maxim et al., 2009). Generalising earlier work specifically dedicated to biodiversity, we suggest the following definitions (environment here referring also to pristine nature, but in particular to the health of anthropogenically managed ecosystems such as rice paddies; reference to ecosystem services added):

DRIVING FORCES are changes in the social, economic and institutional systems and/or their relationships which are triggering, directly and indirectly, Pressures on the environment. Ecosystem service potentials are part of the social system, ecosystem services part of the economic system.[1]

PRESSURES are consequences of human activities (e.g. release of chemicals, physical and biological agents, extraction and use of resources, patterns of land use) which have the potential to cause or contribute to adverse effects on the environment and the services it provides (Impacts).

The STATE of the environment is the quantity of biological features, of physical and chemical features of ecosystems, and of ecosystem functions, vulnerable to (a) Pressure(s), in a certain area.

IMPACTS are changes in the ecosystem functions, affecting (negatively) the environmental health and through a change of ecosystem service potentials, the social, economic and dimensions. Impacts are caused by changes in the State.

RESPONSE is a policy action, initiated by institutions or groups (politicians, managers, consensus groups, etc.) which is directly or indirectly triggered by the societal perception of (potential) Impacts and which attempts to prevent, eliminate, compensate, reduce or adapt to them and their consequences (e.g. by remediation measures, or pesticide spraying).

As illustrated in Fig. 2, Responses may seek to control Driving Forces or Pressures (prevention, mitigation), to maintain or restore the State of the environment, to help to accommodate Impacts (adaptation) or even to deliberately “do nothing” (Smeets and Weterings, 1999; Gabrielsen and Bosch, 2003; Perrings, 2005). A preventive policy will aim at the reduction of Pressures and therefore will address in the first place Driving Forces (i.e. changing behaviour or production patterns, mitigation). A curative policy (end-of-pipe) will only try to diminish the Impacts by adaptation, either through technical solutions such as restoration, cleaning and global monitoring of the environment with reference to politically set but scientifically operationalised quality norms (action on State), or through protection of the impacted social groups (Mysiak et al., 2005). In some cases, deliberate “wait and see” strategies are also a suitable Response.

[1] Other authors have defined service potentials as equivalent to ecosystem functions, the latter having two meanings, the functioning of an ecosystem and the function of a system for human society (Braat and de Groot, 2012). We use the term “ecosystem functions” exclusively in the former meaning, as a part of the ecological system, as it is commonplace in natural science. The definition of a potential use of such functions is a societal process and thus part of the social system, see Spangenberg et al. (2014a).

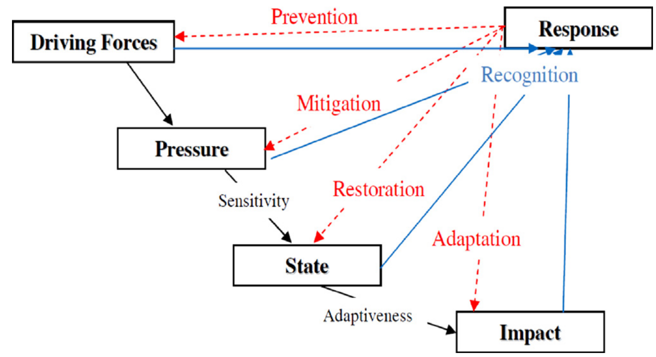

Fig. 2. The extended DPSIR model. Responses only take place if a problem has been recognised, and the epistemology shaping the kind of societal recognition (co-)determines the kind of response. The sensitivity of the ecosystem determines how the state is affected by a certain pressure (sensitivity is pressure-specific), and the adaptiveness co-determines the resulting impacts.

For instance in the case of planthopper infestations, when the State is characterised by increases in pest outbreaks, chemical pollution and insecticide resistance, and the Impact includes farmers’ income loss, rising debt (and even suicides), national loss in export earning, health problems and unstable production, the need to counteract these trends to restore biodiversity and ecosystem resilience to reduce these threats is easily recognised (Heong and Hardy, 2009). In this case, adaptation measures could include financial or physical support, and health and financial services for the severely affected farmers, while mitigation measures against the pressures of unnecessary insecticide use, misuse/overuse and wrong insecticide choice could be a ban on insecticides and training in integrated pest management IPM (Escalada and Heong, 2004). However, this would not address the root causes, the Driving Forces of inadequate pesticide marketing caused by missing, inadequate or unenforced regulations, and misguiding advice from untrained retailers or from extension workers who are supported by the insecticide industry. Nor would it change the underlying mental model justifying the pro-insecticide advice and legitimising their marketing (Escalada and Heong, 2012). Prevention would thus require revising not only the formal institutions of pesticide marketing regulations and the licensing of retailers based on proven skills, but also the mental model in favour of a transition from chemical pest regulation to biological approaches (Gurr et al., 2012).

3. Theory: putting DPSIR from its head back on its feet (and vice versa)

Most literature sources consider only anthropogenic factors as Driving Forces (Gabrielsen and Bosch, 2003; EEA, 2005; Giupponi, 2005; Rogers and Greenaway, 2005; Mysiak et al., 2005). For example, for the EEA, the Driving Forces are considered to describe “*the social, demographic and economic developments in societies and the corresponding changes in lifestyles, overall levels of consumption and production patterns*” (EEA, 2007, p. 13).

However, as the social and the environmental systems are interacting, it is advisable to take a closer look at the different hierarchical structures when analysing the processes structured by applying the DPSIR scheme. For the environmental system, consisting of the State of the environment and the changes induced (Impacts), two levels should be distinguished: the underlying biophysical structures and processes (here biodiversity plays an important role) and the ecosystem functions ESF as emergent properties of the system. The latter provide the basis for indentifying ecosystem service potentials ESP, and for mobilising the potentials to generate ecosystem services ESS (Potschin and Haines-Young, 2011; Spangenberg et al., 2014b). Regarding the social system,

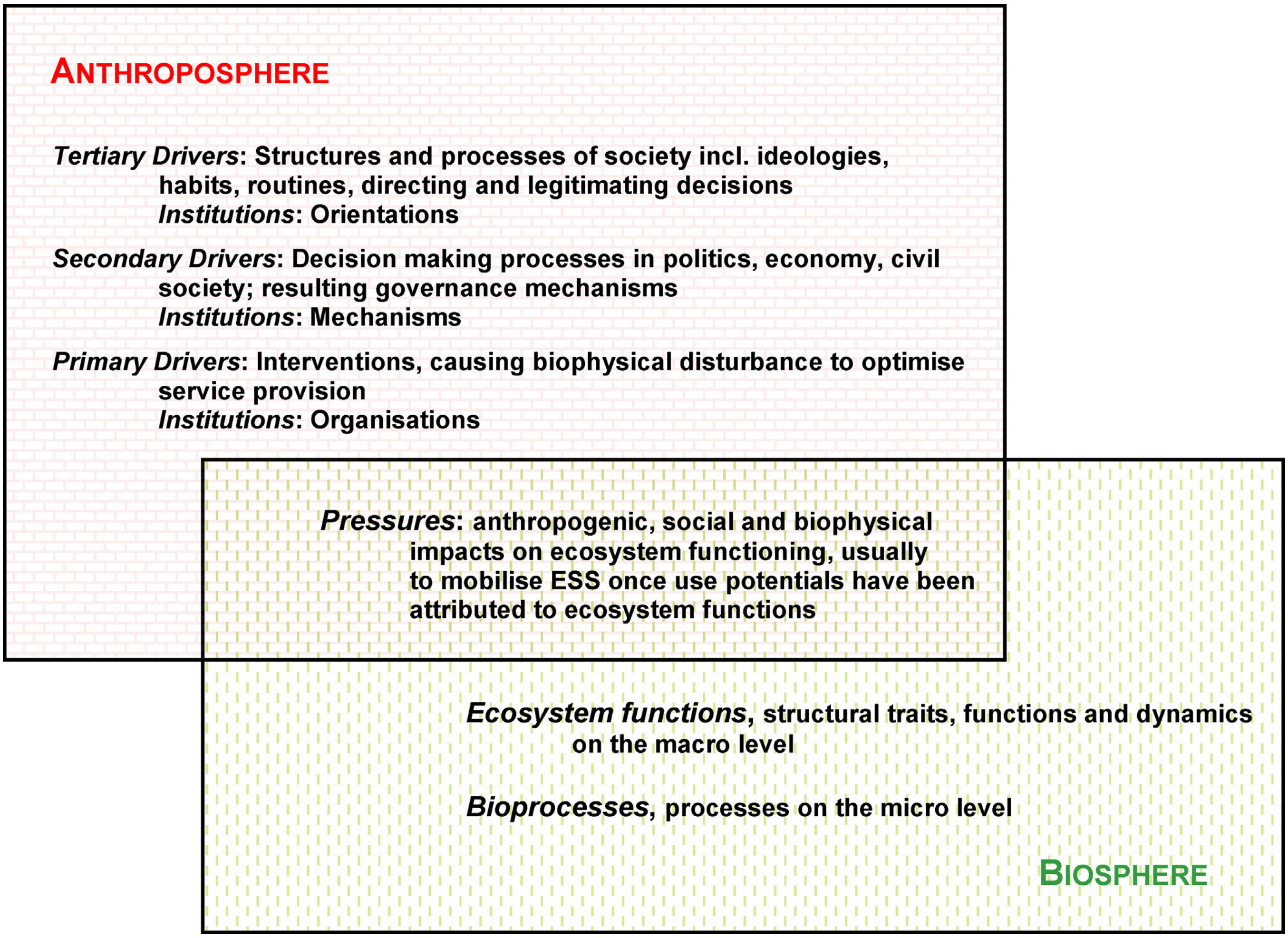

Fig. 3. Interacting system levels and the location of Drivers and Pressures: in the anthroposphere, Drivers on different institutional levels can be distinguished which all affect the pressures generated, but require different strategies for damage prevention. Pressures belong both to the anthroposphere where they are generated, and to the biosphere where they have effects on the State of bioprocesses and ecosystem functions.

one way of structuring its description is doing it according to the three levels of institutions: organisations (the agents) as primary drivers, mechanisms (the rules of decision making) as secondary ones, and orientations (beliefs, ideologies, values, meaning) as tertiary (North, 1990; Spangenberg et al., 2002, see Fig. 3). All three play different roles in generating Pressures, and thus have to be addressed specifically in problem solving strategies. The Pressures are of special importance as they constitute the interface between the social and the environmental system, the biosphere and the anthroposphere.

An “environmental problem” can then originate from the relationships between stakeholders (power balance), from the inefficiency of institutional arrangements in implementing an established regulation, from social inequality (the source of environmental justice conflicts – for instance, dumping waste in poor areas may be cheap), or from the inadequacy of policy actions for a given social context. Human motivations, behaviours and attitudes that induce, are affected by, or respond to the changes in environmental conditions, are highly relevant for framing policy Responses (O’Connor, 1994; Bowen and Riley, 2003). A description of an environmental issue that ignores employment, social receptiveness for the environment or the relative distribution of Impacts between social groups and economic players may lead to a framing of Responses that disregards such aspects.

A different approach has been taken for instance by the Millennium Ecosystem Assessment (MA), proposing that Drivers can be both anthropogenic and natural factors “*that directly or indirectly cause a change in an ecosystem*” (MA, 2003, p. 85). According to this definition, precipitation change, invasive species or natural disasters qualify as Driving Forces.

In conclusion, depending on the objectives of the research, very different descriptions of systems and of the inter-relationships between the environmental and the human systems can be developed. The DPSIR scheme can be “turned”, analysing either the impacts of the socio-economic system on the environment, or vice versa, and with it the definitions given above. Different disciplines in charge require new definitions of D, P, S, I and R rooted in the same reality but perceiving it from a different angle. As a result, different meanings will be attached to the concept of Driving Force and subsequently to P, S, I and R, once the perception of “where” the cause of a problem lies is changed (human and/or natural systems), and the level of the chosen system at which one assumes the problem to originate is decided. We suggest the following definitions for this bottom-up complement:

DRIVING FORCES are naturally occurring or externally induced changes in the environmental processes and structures of ecological systems and/or the functions emerging from them which are triggering, directly and indirectly, Pressures on the society.

PRESSURES are consequences of (changes in) ecological processes (e.g. development of resistance to chemicals, immigration of new species, etc.) which cause or contribute to adverse effects on the socio-economic system (Impacts), for instance the weakening of certain ecosystem services.

The STATE of the socio-economic system is the totality of societal processes, of institutional features of social systems, and/or of socio-economic functions including the ecosystem services they use, vulnerable to (a) Pressure(s), in a certain area.

IMPACTS are changes in the socio-economic processes, affecting (negatively) the environmental (and also the social and economic) dimension, and which are caused by changes in the State.

RESPONSE is a reaction of the environmental system which is directly or indirectly triggered by the Impacts and which serves to compensate them or adapt to them and their consequences. Adaptation implies system change, and with it a change of ecosystem functions and thus service potentials.

4. Result: rice planthopper problems in an extended DPSIR view

Applying the standard DPSIR approach, making use of the refined definitions given above, we can describe the predominant mental model and the resulting problem perception. It sees the cause of the problems in the planthopper infestations, which are the primary Driving Force acting at the micro level. However, the agricultural management passes through this circle twice: first, the occurrence of e.g. *White-Backed* or Brown Planthoppers (perceived as damage drivers, like all hoppers) leads to the expectation of Pressures (reduced ecosystem service potential ESP due to crop damage) and subsequently a loss of the key ecosystem service ESS, the yield, a severe negative impact (Heong et al., 2013; Escalada and Heong, 2012; Escalada et al., 1999; confirmed by own field research). As a Response, the standard control measure against insect damage is applied: spraying insecticides, apparently successful, as many or even most of the insects, including the leaf feeding pest insects are killed. The system seems to have returned to the initial state of undisturbed development.

Some time later – in the same growing season – the problem seems to reoccur: Brown Planthoppers appear, but unlike during the earlier infestation, they multiply rapidly and spread over the paddies in enormous numbers (Heong and Hardy, 2009; Gurr et al., 2011a,b). They affect the biological functions of the system at the macro level, in particular by reducing the net primary production (and thus the ESP). The reduced service potential threatens to diminish or even destroy the harvest, i.e. the ESS, regardless which additional efforts are taken to mobilise as much of the potential as possible. At the Pressure level, the intersection of the biosphere and the anthroposphere, the ecological catastrophe may translate into a societal problem: the State of the harvest is reduced, local income generation fails, even nutrition may be at risk. Of course such a negative Impact calls for adequate Responses, and just as obviously, the Response chosen is the same again, spraying insecticides, in line with the prevailing mental models, attitudes, ideologies and past experiences. However, this time it obviously does not work as much as before, given the number of insects and the speed of their spread, and the damage becomes manifest.

Insecticides are, even if used successfully, no prevention strategy (they do not end the arrival of hoppers), but a mitigation strategy aimed at reducing Pressures at the micro level – a prevention strategy would have to address the Drivers at the level of landscape wide system management. As adaptation to damages is not possible (changing varieties would not solve the problem), only two options remain at the micro level on which this kind of perception is exclusively focussed: restoration, only effective until the next infestation (which is not necessarily next season), and additional mitigation measures like enhancing the crops' insect resistance through breeding and/or genetic engineering. But these methods suffer from the fact that they try to bring about resistance against a single Pressure, but hoppers represent multiple simultaneous Pressures (for instance, all hoppers are potentially vectors tranferring viruses), rendering a micro level approach rather illusionary.

But why does the standard strategy fail? What is overlooked in the micro level analysis is the feedback loop from the societal to the ecological system. The Response chosen, insecticide spraying in the first cycle, acts as a Driver in the ecological system, causing externally induced changes in environmental processes, and thereby triggering a process in the biological system which can also be described by a DPSIR classification. The decision to spray insecticides is the primary Driver, with individuals and organisations like corporations (profit driven), but also extension officers and agro-administrations (rather ideology-driven) implementing it. They follow the existing mechanisms of decision making, routines, attitudes and legal regulations (mechanisms), all legitimised by a similar ideology of improving the standard of living by intensification, mechanisation and chemicalisation (all crude oil dependent) to create additional income and economic growth. The focus on the micro level is similar in this perception of ecological systems, and in economic thinking: the higher system levels and their emergent properties, which are not necessarily predictable from the individual elements, are not taken into account, let alone actively managed.

So what is overlooked is the Pressure on the ecosystem functioning resulting from spraying. The Pressure caused by human management planned to rescue one ecosystem service in the first round threatens a series of others, possibly including water purification and pollination, but in our case in particular reducing the biocontrol potential of the respective system. However, such a change of the State of the system goes unnoticed in the first round, as long as only the ecosystem service potential ESP is affected, not the visible state of ESS provision. Thus the system seems to be undisturbed, back to its State before the Drivers hit – a dangerous illusion.

How dangerous it is becomes obvious once the Driver (infestation) materialises a second time, and the Pressure is turned on. Then it becomes obvious that the sensitivity of the system has increased (its resilience has decreased); it can no longer absorb infestations by limiting their Impact, size and duration. The Impact on the State of the system becomes obvious; the loss of the ecosystem service itself becomes manifest once the infestation has taken place. The resulting increased sensitivity allows hoppers to multiply and spread, leading to a partial or total collapse of the entire systems or some of its parts: the Response of the ecological system forces society to take measures; it is a driver in the societal system – the circle closes again. So while the first cycle result consisted mainly of a reduction of biocontrol ESP, it takes the second cycle to make this damage obvious, at the expense of services partly or completely lost. If spraying is repeated regularly, the system as a whole may flip permanently into a different State, with diminished potentials of important ecosystem services, and thus less benevolent to humans.

Obviously, while the Responses of one loop are the Drivers of the other, the interface of the biosphere and the anthroposphere is the same, but interpreted differently according to the direction of causality under analysis. If only the perception of reality at the interface were broadened, both loops could be easily integrated. This would be all the more important as the first round of the standard environment-to-society loop is based on expected, not on experienced losses of the rice producing ESP (Escalada and Heong, 2004, 2012). In fact, as the damage would be limited without spraying, and occurs early in the growth period, the plants would recover – the real ESS loss would be insignificant (Heong, 2009).

It is thus a double misperception of the society-to-environment loop: in the first run, the resulting potential Impacts are grossly overestimated, leading to massive spraying as a Response, while in the second run the Driver character of the spraying is not seen, and thus the change of the State not recognised as explanation of the severe Impacts. Thus solving the problem would require recognising the society-to-environment loop and acknowledging that it is an inevitable consequence of the environment-to-society loop and has to be managed just as the standard one has to be. However, this step from recognition to management is not self-evident either: it requires a change of perspective, from micro-level, physiology or species-based thinking to ecological engineering and ecosystem management.

5. Discussion and conclusion

The DPSIR scheme as developed by the European Environment Agency has been chosen as the starting point of our intervention because of its proven appeal to decision makers (Stanners et al., 2007). Unlike other heuristics appealing directly to farmers (see for instance the campaigns branded "No early spray" in the Philippines or "Three reductions – three gains" in Vietnam, Escalada and Heong, 2012) addressing their loss aversion and anchoring bias (Tversky and Kahneman, 1974.) which are not easily changed by unsupported information, DPSIR and the Double DPSIR presented in this paper address agricultural policy decision makers.

As in their most frequently used forms the DPSIR definitions are not unambiguous, we have used a more refined version introduced by Maxim et al. (2009). After adapting it to the ecosystem service terminology, we could use it to describe the dominant causality perception starting in the biosphere with biological infestations and resulting in additional insecticide use as a reaction from the anthroposphere. Unfortunately, this perception ignores the human contribution to problem generation, which can be described by a second DPSIR loop starting in the anthroposphere with overuse of insecticides and leading to a collapse of ecosystem functions ESF and the services ESS they provide.

As a one-sided, seemingly 'causal' description of environmental problems inevitably downplays the multiple dimensions of causality inherent in complex environmental and socio-economic systems, only a combined perspective can provide effective solutions (being aware of its inherent simplifications and the unavoidable uncertainty). This signals a clear need to address a failing strategy based on a narrow mental model. Consequently, the paper complements and reframes the standard DPSIR scheme, suggesting a Double DPSIR (Fig. 4) or Double Belly structure (Fig. 5). Both are functionally identical although graphically different and can be used as heuristic tools in different contexts. Not as an analytical tool, but as a heuristic device it might help localising the semiotic and epistemological problems causing the mismanagement of planthopper infestations by illustrating that a change is necessary and possible regarding the interpretation of the Pressure, and thus contribute to overcoming the neglect of societal Drivers and their ecological Impacts.

While the details of the Double DPSIR heuristics have been adapted to the specific situation of rice planthopper infestations in South East Asia, similar challenges exist in other regions as well. For instance, regular insecticide spraying against aphids in European winter wheat undermines biocontrol services just alike, and systematic analyses of how biocontrol could substitute for insecticide spraying are only in the making (see e.g. the EU funded BiodivERsA project APPEAL, http://www2.ekol.slu.se/appeal/). Research results in this field are not only relevant for farmers, they could also have severe implications for the EU Common Agricultural Policy CAP (Krauss et al., 2011; Jonsson et al., 2014). The Double DPSIR heuristic provides a tool to communicate them to decision makers and we hope that those in Europe working with the DPSIR heuristics will

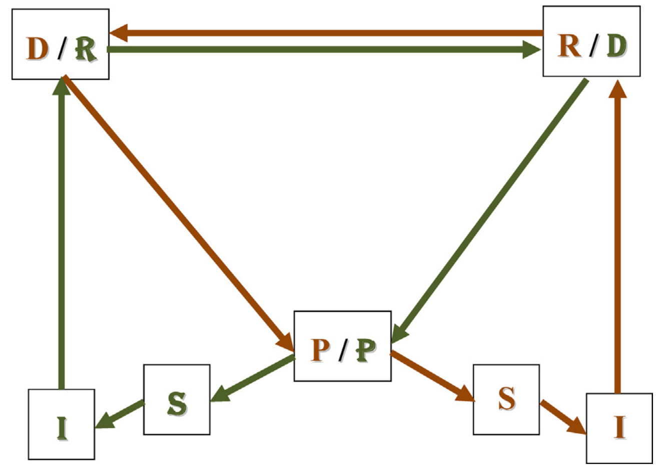

Fig. 4. Combining two DPSIR cycles (the diverse Responses are left out for clarity), with the Responses of one cycle being the Drivers of the other, and vice versa: Land management affects the environment, leading to damaged ecosystem functions with impacts on ecosystem service provision. This triggers insecticide spraying as a Response. In the second DPSIR cycle, this Response drives changes in the ecological system, causing Impacts in society (e.g. changed land management) affecting the environment. Ecosystems may Respond by flipping into a different state, less beneficial to ecosystem service provision.

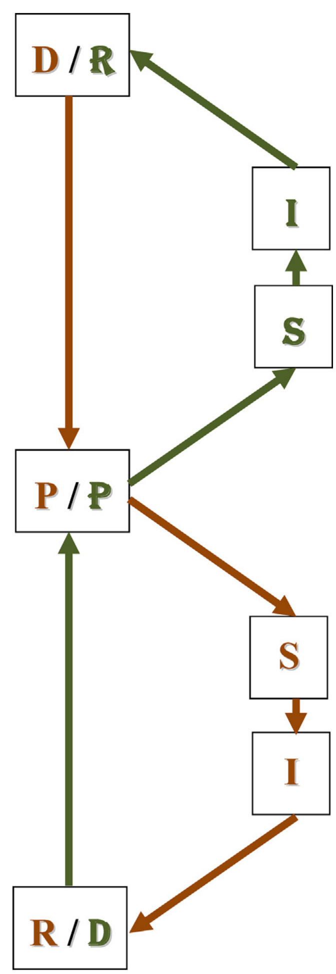

Fig. 5. The B or double belly form of the integrated social and environmental DPSIR cycles. Essentially identical with Fig. 4, it graphically highlights the overlaps of both processes and the feedback mechanisms to be taken into account.

either pick up the Double-DPSIR concept or at least feel inspired to apply the DPSIR heuristic in a more reflexive way.

Thus the ultimate purpose of the analysis is to influence decision-making in relation to agricultural and environmental policy in general, and to infestations in particular, to break out from the lock-in situation of a cycle of continued harmful intervention as described. Stimulating effective learning processes will require rethinking the basic mental model, now applied as self-evident, and reflecting its shortcomings.

5.1. Conclusions

The potential usefulness of this paper for the practical management of planthopper infestations lies in the fact that the tools developed have the capability to point out the deficits and stimulate reflection, potentially leading to a modified approach and ultimately to reduction in harvest losses to planthoppers and other infestations. For this behalf the Double DPSIR heuristic device offers a mechanism and a terminology which are familiar to decision makers (land use planners, administrators, extension workers, etc.). This should help it to resonate with decision makers while highlighting the feedback mechanisms neglected in their prevailing mental model, blinding them against 'green' experience and scientific analysis.

Being mainly a communication tool, the Double Belly DPSIR– although somehow more complex than the initial version – may still be effective (as its conceptual ancestors are) to convey the message if properly used in science–policy interfaces and knowledge brokerage processes. In the best of cases it could contribute to help decision makers recognise the lack of feedback mechanism in their mental model, preventing environmentally benign and thus economically sustainable land management strategies.

Communicating the analytical deficit and raising awareness among decision makers regarding which Drivers have to be addressed by Responses to reduce the Pressures and consequently the undesired Impacts requires introducing the feedback loops into the education and training of administrators and in particular of extension workers. So far, landscape managers (farmer, planners, etc.) have effectively maximised one ESS (yield) at the expense of many others (biocontrol, water purification, etc.), triggering a feedback loop undermining their intended maximisation. Such Responses are derived based on specific problem perceptions, epistemologies influenced not only by limited knowledge and partisan interests, but also by the basic world view and the dominant orientations (which can coincide with and reinforce the interests). However, being fixated on the biology-to-society loop and unaware of its complement, a lock-in of behavioural routines and institutional settings emerges. Thus consultative and development organisations (from FAO to UNDP), but also national administration could use the extended DPSIR model to sensitise their local representatives of this shortcoming.

Any successful strategy to overcome this lock-in, leading from insecticide use to planthopper damage, and on towards more insecticide use and more damage, needs to address the different institutional levels of orientations, mechanisms and organisations. Mechanisms to be addressed are the legal situation (from bans on misguiding advertisement as adopted but not necessarily implemented in Vietnam, to licencing of pesticide dealers based on qualification tests in the Philippines – now pesticide selling licences can be obtained for a fee but without qualification testing). Organisational changes include the regular information of farmers by public extension workers providing independent advice – today pesticide producers' representatives are a key source of information. In the end, however, it will be decisive if the orientations, the simplistic mental model can be modified to be replaced by a new one, incorporating feedback loops and emphasising the complexity of ecosystems managed.

To break up the lock-in, it will be necessary not only to employ knowledge brokerage strategies and science–policy interfaces to achieve a discursive opening, but also public education to make stakeholders aware of their epistemic fallacy: what they considered a true representation of reality was just an epistemology, a view based on a limited knowledge about reality. Public awareness raising will probably not make use of the model (as farmers are usually not aware of the DPSIR concept), but can argue along similar lines when disseminating information e.g. via mass media (Escalada et al., 1999). The Double-DPSIR scheme is suggested as a heuristic device for structuring information, and as a communication tool for conveying the message in a simplified but meaningful way.

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