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

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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.

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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).

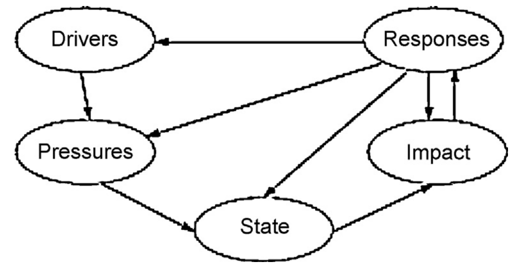

Fig. 1. The DPSIR model (Smeets and Weterings, 1999) assumes a causal chain from Driving Forces in the socio-economic system causing Pressures on the environment which affect its State and cause Impacts on society and economy. These in turn trigger Responses intended to minimise the impacts by addressing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