# Chapter 7

# Scale-Relevant Impacts of Biogas Crop Production: A Methodology to Assess Environmental Impacts and Farm Management Capacities

**Wiebke Saathoff, Christina von Haaren, and Michael Rode**

**Abstract** The cultivation of biogas crops can affect nature and landscapes in different ways. The increasing loss of permanent grassland, changes within cultivated crops, crop rotations and their spatial allocation within the landscape may have serious impacts on natural assets and commercial ecosystem services. Beneficial or impairing impacts occur at the level of interference (farm level) as well as on broader spatial and/or temporal scales. Governance problems often occur when impacts cross farm boundaries, since farmers have no interest in maintaining a service or avoiding impairments. This is due to the beneficiaries on regional and higher scales often not compensating farmers for the costs of the service at the farm level. Environmental governance should therefore deal with the discrepancies between farm activities that have transboundary relevance and administrative/property borders. Our research questions are:

(i) What kinds of transboundary impacts does biogas crop cultivation have on natural assets or ecosystem services?
(ii) How can the harmful or beneficial impacts on different spatial scales or governance levels be assessed? Where do costs and benefits occur?
(iii) Which biomass production impacts require individual and/or collective responses and which precautionary measures could be implemented to avoid possible impacts?

The purpose of this chapter is to establish an assessment methodology to identify the discrepancies between land-use-related decision competencies and the scope of the resulting impacts.

The assessment method is based on a literature analysis and is developed in three steps:

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1. Establishing a theoretical basis to classify the scale-related impacts of biogas crop cultivation. This theory considers the governance problems that may occur if
   - affected habitats or ecological processes cross farm boundaries;
   - the value of an affected natural asset is relevant on a broader scale (regional or even global relevance);
   - small or insignificant pressures (from the farm-level perspective) occur, as they can have a relevant impact if they occur frequently in a larger spatial context.
2. Classifying the typical pressures and impacts of biogas crops;
3. Integrating these pressures and impacts into a DPSIR framework according to their scale relevance.

This methodology provides a systematic analysis of scale-related problems of fit that occur in biogas crop cultivation. The resulting information on the required individual or collective actions supports the identification of suitable governance measures.

**Keywords** Biogas crop production • spatial scale • conservation • ecosystem services • biodiversity • climate protection • greenhouse gas emissions (GHG) • species protection • habitat network • on-site impact • transboundary impact • DPSIR

## 7.1 Introduction: State of Knowledge and Objectives

### *7.1.1 Impacts Through Biogas Crop Cultivation*

As a consequence of different driving forces, such as the strong incentives for energy crop production, biogas crop production has expanded rapidly, accompanied by extensive land use changes. Owing to the rapid expansion of biogas crop production, the maize cultivation area grew by approximately 42 % in Germany between 1999 and 2012 (Statistisches Bundesamt 2002, 2012). This expansion of energy crop production has also increased the competition for land. The biomass production of bioenergy, food, fodder and its extensive utilisation all compete with one another and with nature conservation demands for land. In Germany, and particularly in Lower Saxony, the resulting changes include the conversion of grassland into arable land and the increased use of land that was previously set aside (Nitsch et al. 2010). These land use changes have also occurred in ecologically vulnerable areas, for instance, in areas protected by the flora and fauna habitat directive, in water protection areas, on sites vulnerable to erosion and in areas with great significance for carbon storage, such as peatlands (Nitsch et al. 2009, 2010; Buhr et al. 2010). Grasslands have increasingly been converted into cropland, particularly on sites that are relevant for $CO_2$ retention and species protection, such as peatlands (Nitsch et al. 2009, 2010). Further changes are caused by increasing pressure to use arable land more intensively, which is often followed by reduced crop rotation times, the introduction of new energy crops, changes in irrigation practices and an increase in plot sizes. These often have negative effects on ecosystem services, such as the impairment of habitats (definition according to Abercrombie et al. 2008) through the reduction of hedgerows and field margins, changed species composition and the deterioration of landscape amenities (Wiehe et al. 2010; Rodrıguez and Wiegand 2009).

## *7.1.2 Problems of Scale*

The described unwanted landscape changes through biomass cultivation are partly due to scale problems. They occur if the (e.g., economic) interest on the farm level differs from that on the higher levels (e.g., regional habitat network), or if the farmer overlooks the effects on the higher scales. The terms “level” and “scale” will be used in this paper as follows: The term “scale” describes the definite spatial or temporal boundary of a quantitative entity, whereas “level” is defined as a unit of organisation (Allen 1998), which can be also spatially defined, confined by political boundaries.

Land use changes and intensification can adversely affect natural assets, such as animal species diversity and population density, if energy maize is cultivated on a large area (Rode et al. 2010; Reich et al. 2011). However, maize cropping can also result in beneficial effects if it diversifies the crop rotation, thus enriching the habitat supply for animals (Reich et al. 2011). Positive and negative effects can occur at the level of interference on the farm scale, but also on a broader spatial scale. In the latter case this occurs if, for instance, many farmers act similarly and all introduce maize resulting in large areas with monocultural maize cultivation. On a broader temporal scale (over longer time spans), such changes may contribute to gradual global warming caused by the GHG (greenhouse gas) emissions (IPCC 1996). The Brundtland Report and others have acknowledged the importance of considering temporal and spatial scales in environmental management (World Commission on Environment and Development 1991). Understanding an impact’s spatial (and temporal) extension is necessary in order to identify the sources of a problem and to implement measures to prevent impacts, or to rehabilitate affected ecosystems.

### 7.1.3 Information and Methodology Deficits Regarding Managing Scale-Related Environmental Conflicts

Environmental impacts and their spatial dimensions caused by biogas crop cultivation are seldom foreseen or acknowledged on the spatial scale where crop cultivation decisions are made (the farm level) (see Wiehe et al. 2011). This shortcoming in forecasting is, at least partly, due to a problem of fit between the decision level for crop cultivation and the scale of the resulting impacts. According to the subsidiarity principle, it is preferable to solve environmental conflicts at the lowest possible decision tier (e.g., European Parliament 2000). Applying this principle would imply that as many impacts as possible should be prevented and reduced at the farm level. In order to enable the farmer to accept these responsibilities, he needs information about the imminent environmental impairments and compensation for the management measures he may take that are not in his economic interest. The framework conditions for such management on the farm level, or for issues that cannot be dealt with at the farm level, should be managed at higher decision tiers (EURLex 2002, Art. 174, environmental part of the EC treaty). Spatial planning is a discipline which is capable and qualified to decide on the right level of management. In Germany, spatial planning is the responsibility of forward-looking regulations and the governance of territorial functions. This includes bridging different spatial levels (counter-flow-principle) and acting according to the precautionary principle (Regional Planning Act 2009). Spatial planning has to coordinate different land use demands and deal with conflicts on different planning levels. Specifically, spatial planning, together with landscape planning, should develop, conserve and – if possible – restore soil functions, water balance, flora and fauna, climate and cultural landscapes' functions, as well as their interactions. The spatial requirements of habitat networks, climate protection (climate change mitigation) and climate change adaptation should be considered. Spatial planning should set the stage for agriculture and forestry to help conserve rural areas' natural livelihoods as well as to maintain and design nature and landscapes (e.g., ROG 2009, §2 (1, 5, 6), (Regional Planning Act 2009)). In order to follow the precautionary principle and to prevent potential spatial conflicts, the risk of such conflicts should be identified at the outset (Rode 2006). In addition, to fulfil its scale-related governance tasks, spatial planning requires competencies in managing the financial compensation of land users, who should be motivated to act against their intrinsic economic interests.

To date there has been no systematic analysis of a suitable division of tasks between the regional planning level and the farm level with respect to the scale-related problems that bioenergy production causes. The capacity of the farm level to solve problems has specifically not been systematically examined. According to the subsidiarity principle, knowledge of farm-level capacities could be the precondition to decide on the appropriateness of the decision competencies at higher governance levels. A classification of the scale effects and a methodology that can serve as a basis to identify the adverse effects or benefits of biogas crop management as well as its consequences for responses on different governance levels, are lacking. Providing farmers with knowledge of the impacts that their cultivation practices cause on different scales may improve their capacities to prevent ecological conflicts. However mere knowledge alone may not sufficiently motivate farmers to apply conservation measures. Notwithstanding, this knowledge is also an important basis for governmental institutions to supply incentives or create legal obligations that may support a farm to produce biogas crops sustainably.

### *7.1.4 Objective and Outline*

In order to support regional governance institutions in their attempts to solve problems related to biogas crop production, the following questions need to be answered:

- What are biogas crop cultivation's impacts on the natural assets or ecosystem services and how can we recognise and classify transboundary impacts?
- How can the harmful or beneficial impacts on different spatial scales or governance levels be assessed?
- Which response measures are appropriate and on which institutional level should these measures be initiated or implemented?

A methodological concept is presented that helps answer these questions in concrete cases. Applying the methodology allows the spatial scale-related problems originating from biogas crop production to be assessed. The approach identifies potential options for farmers to ecologically optimise their farm management as well as the potential scale-related obstacles that may prevent them from doing so. Furthermore, the methodological concept allows an assessment of whether conservation measures can theoretically be initiated from the farm level or whether supra-local or even supra-regional scale governance initiatives are required.

Since biogas crop cultivation can affect a wide range of natural assets and ecosystem services, we will focus on species and habitat conservation (the habitat function) and the mitigation of greenhouse gas emissions (the climate regulation function) as examples. We also concentrate on the spatial scale and not on the temporal scale.

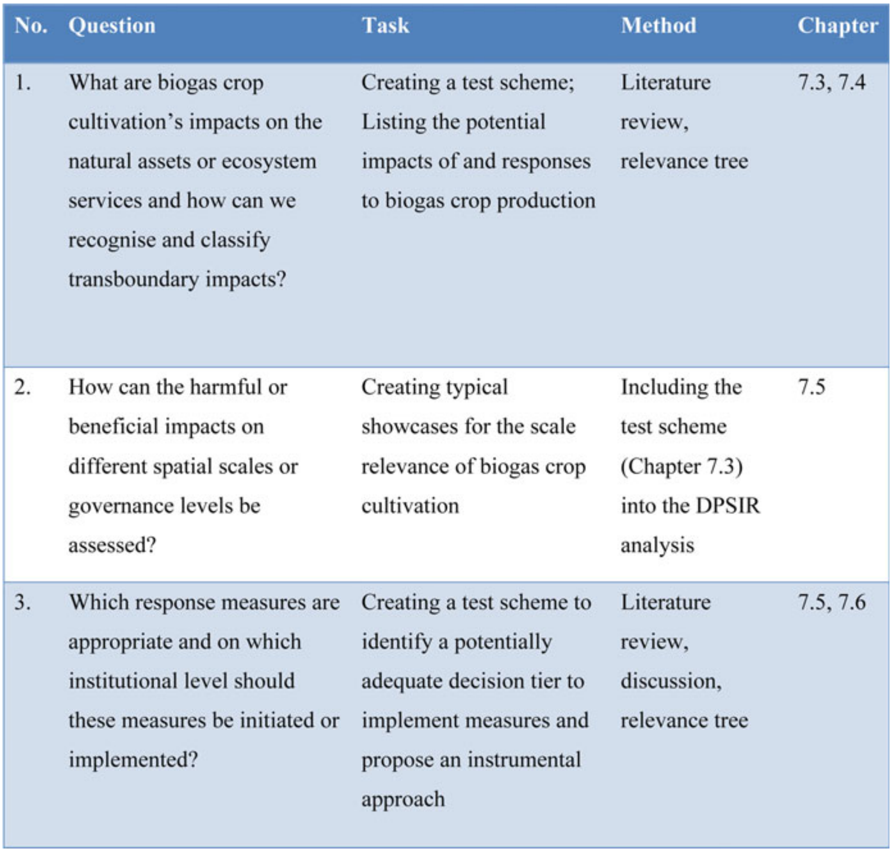
After describing the development of the methodology (Sect. 7.2), we explore the scale relevance of impacts and propose a test scheme for identifying different decision levels' responsibilities and regulation capacities (Sect. 7.3). Typical impacts of biogas crop cultivation and measures to mitigate them (Sect. 7.4) are used to integrate the test scheme (described in Sect. 7.3) into a DPSIR (**d**riving force, **p**ressure, **s**tate, **i**mpact, **r**esponse) analysis. Thereby, the scale relevance of biogas crop production's possible impacts and response options is assessed. Suggestions are made (Sect. 7.6) on how to use the test scheme and the adopted DPSIR concept to identify the right planning level for response options. Finally, the scale relevance of impacts and responses' benefits and costs is discussed (Sect. 7.7) before a conclusion is drawn about the potentials and restrictions of the methodological concept and their implications for planning and governance practice (Sect. 7.8).

## 7.2 Methodological Approach

A methodological framework that incorporates specific tasks and methods was developed in order to answer the questions stated above. Table 7.1 provides an overview of the tasks and methods applied to answer the research questions.

Theories about the scale relevance of environmental impacts due to agricultural land management were analysed by reviewing the relevant literature. Scale relevance, which also applies to pressures regarding biogas crop production was then classified (Sect. 7.3). Next, this classification was integrated into the DPSRI analytical framework (European Environment Agency (EEA) 2007) (see Box 7.1), where it was used to demonstrate the scale relevance of potential biogas crop production pressures and impacts. Therefore, examples of potential biogas crop production pressures and potential impacts on the habitat and climate regulation function were collected from the literature. Potential responses to these impacts as

**Table 7.1** Sections of the methodological framework: questions, tasks and methods



| No. | Question | Task | Method | Chapter |
|---|---|---|---|---|
| 1. | What are biogas crop cultivation's impacts on the natural assets or ecosystem services and how can we recognise and classify transboundary impacts? | Creating a test scheme; Listing the potential impacts of and responses to biogas crop production | Literature review, relevance tree | 7.3, 7.4 |
| 2. | How can the harmful or beneficial impacts on different spatial scales or governance levels be assessed? | Creating typical showcases for the scale relevance of biogas crop cultivation | Including the test scheme (Chapter 7.3) into the DPSIR analysis | 7.5 |
| 3. | Which response measures are appropriate and on which institutional level should these measures be initiated or implemented? | Creating a test scheme to identify a potentially adequate decision tier to implement measures and propose an instrumental approach | Literature review, discussion, relevance tree | 7.5, 7.6 |

**Box 7.1 The DPSIR Analysis: Driving Forces, Pressures, State, Impact and Responses**

The DPSIR (driving force, pressure, state, impact, response) analysis is a methodological structure to assess the impact of a specific pressure or of developments (e.g., the use of resources or land use changes), depending on the physical, chemical or biological condition of a considered site (Hák et al. 2007). Moreover, the method refers to the reason for (the driving forces of) the pressure, such as social, demographic and economic developments in societies and their influence on changing lifestyles, consumption and production patterns. In addition, measures or concepts can be listed to reduce or prevent an impact or response (Hák et al. 2007).

reported in the literature were then listed (Sect. 7.4). Examples from these lists were applied to the DPSIR analysis (Sect. 7.5).

The adopted DPSIR analysis can be used to assess the spatial scale relevance of potential driving forces and pressures of biogas crop production, the state of the affected site and the impacts on the habitat and climate regulation function. On this basis, response measures can be proposed. The DPSIR is a suitable structure for environmental impact studies and to derive practical and governance measures in concrete planning situations (Stanners et al. 2007). Integrating the scale relevance perspective into this structure is a new, still unexplored, step in the context of biogas production as well as beyond.

## 7.3 Criteria for the Scale Relevance of Biogas Crop Production

### *7.3.1 Theoretical Background: Problems of Fit*

Ecological processes and interactions cross the boundaries of ecosystems and properties. Prey-predator interactions, the nutrient and water supply and other complex ecological relationships create specific vegetation patterns and biocenosis with high spatial scale sensitivity and a variety of ecological system boundaries (Veldkamp et al. 2011). In addition, the boundaries of ecological systems (e.g., cell – tissue – leaf – branch – tree – stand – forest – eco-region) (see Veldkamp et al. 2011) differ vastly from the boundaries of social systems, for instance, from governmental levels such as the local, provincial, national or intergovernmental level (see Cash et al. 2006). However, the impacts on ecological systems, which are relevant on different scales, are often not managed by the most suitable level of the societal system. For example, a habitat is managed on a local level, which has no competencies to include this habitat's function into a regional network. Such mismatches between the level of the decision-making authorities on the one hand and the spatial system levels of de facto ecological impacts, or the related pressure sources and driving forces, on the other are quite common in environmental governance (Lutze et al. 2003).

In the literature, the scale mismatch between the management institution's authority or jurisdiction and the ecological impact is commonly described as a "problem of fit" (e.g., Cash et al. 2006; Young 2002; Folke et al. 2007), or as a "cross-scale", "cross-level" (Cash et al. 2006; Gibson et al. 2000) or "transboundary" problem (Cash et al. 2006). This is especially true if the responsibility is located at a lower level than the reach of the ecological relevance. The conservation of ecological processes that transcend the boundaries of single jurisdictions, such as species migration between habitats, or the climate regulation function, is a major challenge for governance (Young 2002; Cash et al. 2006). Such discrepancies between ecological areas and processes as well as decision-making authorities' spatial scope of responsibility often result in unsustainable resource management (Folke et al. 2007). For example, the protection of a globally threatened species will always be a challenge for a regional authority where this species is still abundant. A solution could be to assign decision competences to higher administrative levels if the areas, processes, or the cumulative impacts of many single decisions (pressures) cross the borders of the own responsibility scope. Assigning decision competencies to higher governmental levels is also recommended if the affected natural asset is locally common but rare or even threatened at the higher level (Haaren et al. 2012). However, as in our example of a globally threatened species, protection would be difficult to implement from very high decision levels. Alternatively, divided competencies (e.g., legislation or incentives from higher decision tiers but implementation at a low level) could prevent problems. Not least, environmental impact management can only be successful if we know the spatial scale relevance of the pressure, state, impact and response options. Adequate information is a precondition for scale-sensitive governance. The DPSIR model can structure the modelling of future or existent ecosystem functions and services' impairments as well as the role of responses (management) (Sect. 7.2). All components of the DPSIR model also have a scale dimension. If, for example, an impact like water pollution crosses administrative boundaries because the affected ecosystem processes in a river ecosystem (state) cross these boundaries and the driving forces of the impact (economic frame conditions) are defined on yet another level, then response measures have to take these scale differences into account.

The DPSIR analysis (see Sect. 7.2) assesses the intensity of an impact according to the intensity of the pressure and the state, i.e. value and the sensitivity of the affected natural asset in relation to the considered pressure source. Not only the intensity, but also the scale of an impact is influenced by pressure and state. If we consider the scale relevance of pressure and state, we can also draw conclusion about the scale relevance of the impact and, specifically, about the required response level. This again supports targeted governance actions.

In the following, we define the relevant scale effects related to the pressure and/or state that initially determines impacts' spatial reach. In a next step, these scale effects are included in a test scheme to identify whether an impact is a transboundary or an on-site one. This information is required to identify the response level.

### 7.3.2 Scale Relevance of Pressure Sources

The pressure indicator in a DPSIR analysis describes an action's type and/or intensity, such as the use of land and other resources, as well as the release of substances and the biological and physical agents (Stanners et al. 2007). Beyond the type or intensity, the amount of responsible pressures, i.e. whether there are **single or multiple pressure sources,** also influences an impact's extent (Parker and Cocklin 1993). Individually, the undertaking of a certain farming activity (e.g., the conversion of a single grassland plot into cropland) can be without relevant negative effects for a natural asset (e.g., no complete habitat loss for a depending species, since other grasslands are nearby and migration to these is still possible). Practised by multiple individuals however (e.g., conversion of a whole grassland region), it may cause significant ecological impacts (e.g., regional extinction of species due to regional habitat loss – no habitats left to which species could migrate to) (Parker and Cocklin 1993). According to our test scheme, a transboundary impact occurs as the result of multiple pressures if multiple farmers' management jointly contributes to a compounding or additive impact that goes beyond their individual farm boundaries. We thus presume that the considered natural asset/ecosystem service is not affected by a single pressure, but that multiple pressures are required to seriously disturb the process of the service (e.g., not a single but multiple stressors releasing GHG are responsible for global warming). In the literature, the scale effects of multiple pressures have been described as "space crowding" (Roots 1988) or "structural surprises" (Noble 2010; Peterson 1987; Sonntag 1987; Hegmann et al. 1999).

### 7.3.3 Scale Relevance of State

The state indicator describes the quantitative and qualitative dimensions of the physical, biological and chemical conditions on a certain site/area (Stanners et al. 2007). The state is characterised by the values of the potentially affected ecosystem's functions and their sensitivity to influences (Schenk et al. 2007). The sensitivity describes the extent to which an affected ecosystem function responds to pressures (a positive expression would be resilience). Sensitivity becomes only relevant in case of pressure. If the ecosystem crosses farm boundaries, also pressures outside the farm may lead to on-farm changes (see Table 7.1) in case of a high sensitivity of the ecosystem and vice versa. A common example is a watercourse which will react strongly to pollution and change ecosystem functions and services in different spatial contexts.

Also the value dimension of the affected natural asset/ecosystem's is scale relevant. A transboundary, value-related impact occurs, for instance, if the impaired natural asset/ecosystem service is valuable from a political perspective, or another decision level above that of the farm level (e.g., a nationwide endangered species influenced at the farm level) (Fig. 7.1). Official directives and legislation, or technical

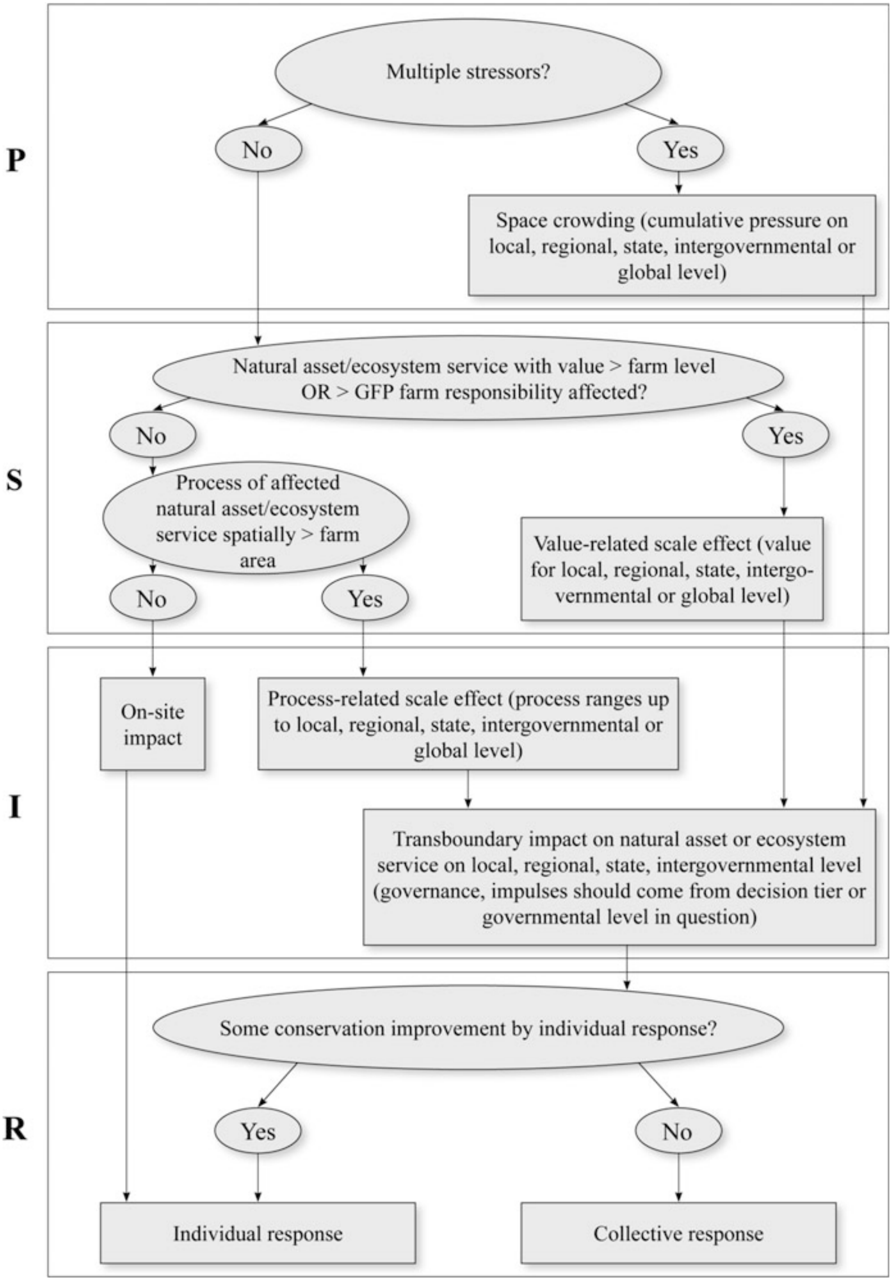


**Fig. 7.1** Test scheme: Identifying the scale relevance of pressure, state, impact and response in DPSIR assessments

recommendations – such as the Kyoto Protocol (United Nations 1998), the Wild Bird Directive, (Directive 2009/147/EC on the conservation of wild birds) and the International Union for Conservation of Nature and Natural Resources (IUCN), which publishes the Red List of globally threaten species –, define the spatial value of a natural asset or ecosystem service. According to the benchmarks of species conservation regulations – such as the Directive on the Conservation of Wild Birds (2009/147/EC, Directive 2009/147/EC) – a caused impact's spatial relevance increases when a threaten species is affected. The relevance for the species' general survival is higher if it is globally threatened by extinction (e.g., according to the Red Lists (IUCN 2001)) than if it is a locally endangered population.

### *7.3.4 Scale Relevance of Impacts*

The impact indicator of the DPSIR analysis describes the relevance of changes in the state of a natural asset/ecosystem service (Stanners et al. 2007). The impact's spatial extent depends on a combination of the pressure intensity, the site-specific sensitivity (Stanners et al. 2007) and the value of an affected natural asset.

Transboundary impacts can also occur if an impaired biotope or process – such as animal migration or nutrient transportation – crosses the pressure level's boundaries (e.g., a farm) (for the process-related scale effect see Fig. 7.1). We created a test scheme to check whether pressure sources from agricultural land management lead to transboundary impacts by considering all spatial scale effects, such as space crowding and value, or process-related scale effects. This scheme will answer the following questions:

1. Are multiple stressors required to cause a relevant impact on a specific natural asset/ecosystem service (for the **space crowding effect**, see Roots 1988; Parker and Cocklin 1993; Noble 2010)?
2. Does the impact affect natural assets/ecosystem services considered valuable at higher governance levels (**value-related scale effect**)?
3. Do the farm-level (on-site pressure) impacts of biological, physical or chemical processes on an ecosystem exceed farm-level boundaries (**process-related scale effect**)?

In order to answer these questions, the governmental level at which the impact may be relevant should be examined in order to identify a suitable level at which to manage and coordinate prevention or conservation measures. The answers are relevant for planning practice and other forms of governance in order to derive suitable response measures.

### *7.3.5 Scale Relevance of Responses*

Land use decisions can respond to impacts by applying measures to prevent, reduce, ameliorate or compensate them, or by adapting to the changes (Stanners et al.

2007). Having identified whether a transboundary or on-site impact occurred and if more than one individual is responsible for it, the next consideration should be whether an individual effort would be sufficient to reduce/prevent this impact, or whether collective actions are required.

If just a single farmer is responsible for an impact, he or she could theoretically address the consequences of the source within his or her scope of competence. Collective efforts (a **collective approach**) are required to reduce an impact if more than one individual is responsible for this impact and if individual measure applications would not lead to improvement. Such collective approaches can be organised by the responsible group of farmers or at a higher government tier by an administration or even induced, for example through public opinion.

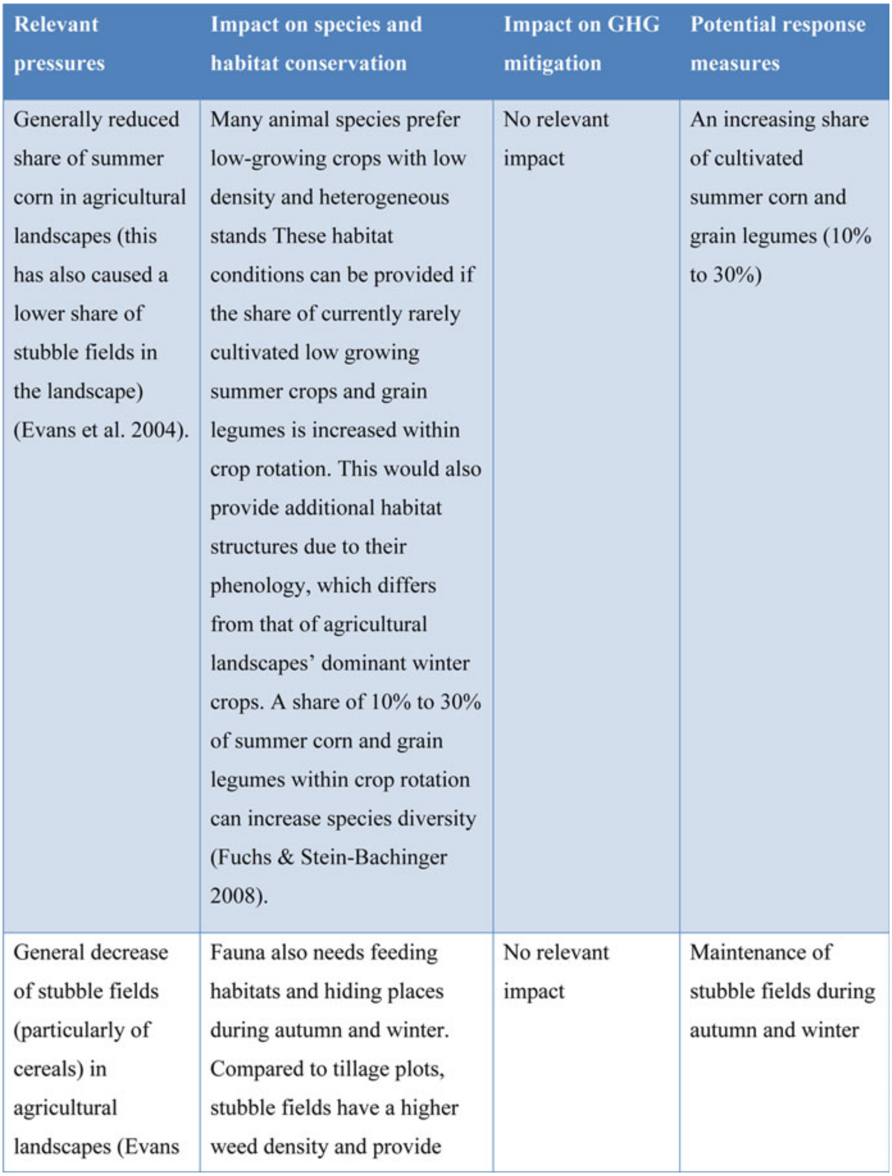
## 7.4 Assessing the Pressures, Impacts and Measures in Biogas Crop Production

At the plot level, biogas crop production's impacts do not differ significantly from those of food and fodder crop production. This is because biogas crops such as maize and cereals are also the main common food and fodder production crops (Statistisches Bundesamt 2012). However, the differences become clearer from the landscape perspective, because a biogas plant's operations may, for example, lead to a change of regional crop rotation by increasing the share of preferred substrate crops (Wiehe et al. 2010). In Germany, this is mainly maize (DBFZ 2011), which is often concentrated in monocultural cropping systems close to biogas plants (Kruska and Emmerling 2008).

The cultivation of single biogas crops such as maize often competes with other spatial demands and may impact ecosystem services such as climate regulation or the habitat function for species (Buhr et al. 2010). Table 7.2 lists the potential general impacts on the habitat and climate regulation function, the underlying pressure factors of biogas crop production and the potential response measures to prevent or reduce these impacts. The main impact of biogas crop production related to feed and fodder production is caused by its monocultural crop production close to biogas plants and its additional demand for land, which result in an intensified use of land (Wiehe et al. 2010). Consequently, the presented impacts and measures mainly refer to the reduction of intensive agriculture's negative impacts on species, habitat and climate conservation. However, the characteristic potential impacts of the biogas sector are mentioned separately in Table 7.2.

Further potential impacts can occur if food and fodder crops are replaced with biogas crop cultivation, through different cultivated crops' water consumption, through machine operations, tillage, humus depletion, pest control and fertilisation (Wiehe et al. 2010). Intensified nitrogen fertilisation may also lead to higher $N_2O$ emissions and thus impact climate protection negatively. Intensified nitrogen input can be caused due to the cultivation of crops with higher nitrogen demands, or

**Table 7.2** Potential pressures and impacts from intensive (biogas, food, etc.) crop production on the habitat and climate regulation function and response measures for impact regulation



| Relevant pressures | Impact on species and habitat conservation | Impact on GHG mitigation | Potential response measures |
|---|---|---|---|
| Generally reduced share of summer corn in agricultural landscapes (this has also caused a lower share of stubble fields in the landscape) (Evans et al. 2004). | Many animal species prefer low-growing crops with low density and heterogeneous stands These habitat conditions can be provided if the share of currently rarely cultivated low growing summer crops and grain legumes is increased within crop rotation. This would also provide additional habitat structures due to their phenology, which differs from that of agricultural landscapes' dominant winter crops. A share of 10% to 30% of summer corn and grain legumes within crop rotation can increase species diversity (Fuchs & Stein-Bachinger 2008). | No relevant impact | An increasing share of cultivated summer corn and grain legumes (10% to 30%) |
| General decrease of stubble fields (particularly of cereals) in agricultural landscapes (Evans | Fauna also needs feeding habitats and hiding places during autumn and winter. Compared to tillage plots, stubble fields have a higher weed density and provide | No relevant impact | Maintenance of stubble fields during autumn and winter |

(continued)

**Table 7.2** (continued)

| Relevant pressures | Impact on species and habitat conservation | Impact on GHG mitigation | Potential response measures |
|---|---|---|---|
| et al. 2004). | plant residues. Since tillage plots dominate in agricultural landscapes, stubble fields are a rare feeding source during this season for, for example, granivorous birds (e.g., Moorcroft et al. 2002). The reduction of stubble fields thus increases the lack of food supply for species in winter, which can threaten their survival in an area. | | |
| The demand for cropland has increased with the extension of biogas crop production. Large areas of permanent (including hydromorphic) grasslands and set-aside land have been converted into cropland, also for the cultivation of biogas crops (see Nitsch et al. 2010; Rode & | The general value of a habitat for species conservation differs with its type. Cropland, for instance, is less important than grassland; intensive grassland is less important than extensive grassland (e.g., Bierhals et al. 2004). Permanent grasslands (Gardi et al. 2002), particularly extensively used pastures (Riecken et al. 2002), permanent pastures or wetland grasslands (Plantureux et al. 2005) are important habitats for many species. Maintenance of an adequate share of grasslands | Maintenance of permanent and particularly hydromorphic grasslands and set-aside areas conserves the soil's organic carbon storages (Neufeldt 2005; Höper 2008) and thus the landscape's climate regulation function. | |

(continued)

**Table 7.2** (continued)

| Relevant pressures | Impact on species and habitat conservation | Impact on GHG mitigation | Potential response measures |
|---|---|---|---|
| Kanning 2010). | at the landscape scale secures habitat and networks for many species. Reducing grassland (especially species-rich grassland) and set-aside land due to the expansion of biogas crops diminishes a farm's overall habitat value. | | |
| Plot enlargements and the associated expulsion of border structures such as margins (Wiehe et al. 2010; Rodrıguez & Wiegand 2009). Consequently, there is a general lack of herbal vegetation cover in agricultural landscapes. | The reduction of blossom habitat structures in agricultural landscapes reduces the gene pools of regional weed species. The clearance of field margins decreases the habitat structures of many species such as insects and their predators. These structures are particularly important in winter, because there is a general lack of overwintering herbal vegetation cover in the agricultural landscape to supply feeding and hiding habitats for a large number of animal species. | No relevant impact | |
| Whole crop silage within a two-cropping system is | Earlier harvest times coincide with many species' breeding seasons. Earlier harvesting | No relevant impact | Preventing the disturbance of breeding habitats |

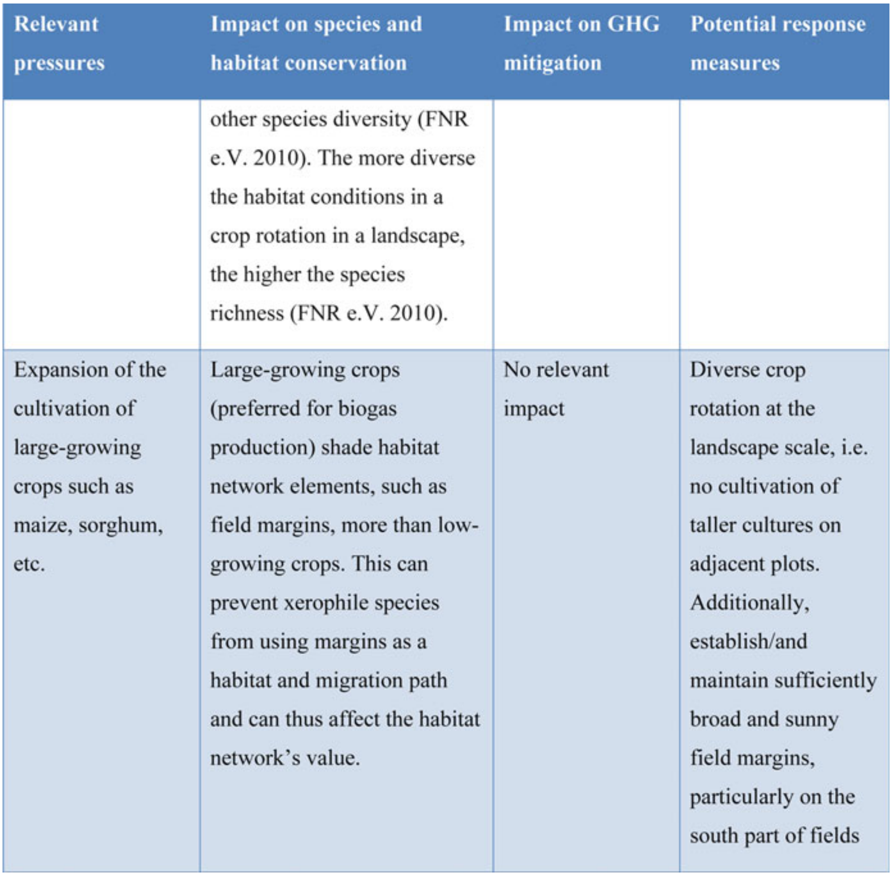
(continued)

**Table 7.2** (continued)

| Relevant pressures | Impact on species and habitat conservation | Impact on GHG mitigation | Potential response measures |
|---|---|---|---|
| a typical practice in biogas crop management. Harvest dates are 3 to 5 weeks earlier with regard to whole crop silage compared to food and fodder crops (Sticksel et al. 2010). | disturbs or even exterminates many individuals of a population and leads to poorer habitat conditions for arable weeds and/or animal species (Dziewiaty & Bernardy 2007; Dziewiaty & Bernardy 2010; FNR e.V. 2010) | | (especially breeding birds) due to earlier harvesting by delaying harvest dates (Dziewiaty & Bernardy 2007) and/or cultivating other biogas crops[1] |
| Maize is the main crop for biogas crop production (Weiland 2010). In some regions, there is a tendency to monocultural cultivated maize stands close to biogas plants (Kruska & Emmerling 2008). | As maize is the main crop used in biogas plants, it displaces other crops in the crop rotation. If this leads to a contraction of the crop rotation at the farm level or landscape scale, the survival of arable weed diversity and other dependent species can be seriously affected (Marshall et al. 2003; Stevenson et al. 1997; Murphy et al. 2006). If a crop rotation is dominated by one or more crop species to a monocultural extent, the inclusion of maize can enrich a crop rotation and have positive effects for weed and | No relevant impact | Diversification of crop rotation (at least fourfold per farm, Wiehe et al. 2010) |

(continued)

**Table 7.2** (continued)



| Relevant pressures | Impact on species and habitat conservation | Impact on GHG mitigation | Potential response measures |
|---|---|---|---|
| | other species diversity (FNR e.V. 2010). The more diverse the habitat conditions in a crop rotation in a landscape, the higher the species richness (FNR e.V. 2010). | | |
| Expansion of the cultivation of large-growing crops such as maize, sorghum, etc. | Large-growing crops (preferred for biogas production) shade habitat network elements, such as field margins, more than low-growing crops. This can prevent xerophile species from using margins as a habitat and migration path and can thus affect the habitat network's value. | No relevant impact | Diverse crop rotation at the landscape scale, i.e. no cultivation of taller cultures on adjacent plots. Additionally, establish/and maintain sufficiently broad and sunny field margins, particularly on the south part of fields |

[1] according to Dziewaty and Bernardy (2007), impacts on breeding habitats can be excluded by means of a harvest date from mid-June onward

through the conversion of a land use type with lower nitrogen demand, such as extensive grassland, into a land use type with higher nitrogen demand, such as croplands.

## 7.5 Integration of the Biogas Case into the DPSIR Framework

For environmentally sustainable biogas crop production, farmers need site-specific information to prove whether or not their biogas crop production causes impacts on and/or beyond their farms. Furthermore, they need to know about potential responses and whether individual implementations of various measures can successfully prevent or reduce such impacts. An adaptation of the classical DPSIR concept (see Sect. 7.2) can help decision-making authorities define whether there has been a **transboundary impact** or if an impact is restricted to the own spatial decision scope. This is relevant information in order to clarify responsibilities and check the level at which measures should be applied to prevent or reduce an impact. An analysis with the adopted DPSIR analysis can help assess:

- whether impacts occur at the farm level or whether the spatial expansion of the impacted ecosystem service has a wider reach;
- whether the reach of an impact depends on the type of pressure and its single or multiple occurrence, or
- on the site-specific sensitivity of a considered natural asset or ecosystem service and its value at different spatial levels;
- which measures can help reduce impacts;
- whether measures can be applied individually, or whether collective efforts are required to prevent or reduce an impact;
- whether the driving forces should be changed for an effective solution.

Table 7.3 shows the results of such an analysis by assessing examples of potential biogas crop production pressures on the habitat and climate regulation function.

Table 7.3 shows the dependencies between the pressure and the state of the chosen virtual site examples, which represent potential German agricultural landscapes and their spatial relevance for the climate regulation function as well as for the habitat and habitat network function.

### *7.5.1 Example 1: Climate Regulation Function*

Substantial funding for bioenergy from renewable resources through the German Renewable Energy Source Act (EEG) has stimulated high biogas crop yields and thus increased the demand for cropland (**driving force**). Besides other reasons, such as the decrease in livestock farming, rising market prices for agricultural products and the decoupling of direct payment due to EU agricultural reform (which made land use changes possible), the biogas boom has led to the increased conversion of grasslands into cropland (Nitsch et al. 2010).

Furthermore, the grassland conversion rate in many German federal states has increased rapidly during the past few years (Behm 2008, 2011). The conversion of permanent grassland into cropland (**pressure**) has led to the decomposition of soil organic carbon and, thus, to $CO_2$ and – to a lesser extent – to $N_2O$ emissions (Janssens et al. 2005; Smith et al. 2004; Soussana et al. 2004). The reduction of carbon storage affects the climate and impairs the climate regulation function of grassland areas (**impact**; Degryze et al. 2004; Del Gado et al. 2003; Lal 2003). The more grassland areas of one soil type are converted into cropland (**multiple pressure, space crowding**), the higher the GHG emissions. However, soil types

**Table 7.3** DPSIR analysis: overview of examples of different potential impacts on the habitat and climate regulation function due to biogas crop production

| Example | Driving force | | Pressure | | State[2] | | Impact | | Response | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Factor | Governance level | Factor | Single or multiple (S[1]) pressure (stressors) | Factor | Scale relevance (P, V[1]) | Factor | Scale Relevance (transboundary; on-site)[3] | Factor | individual or collective effort required to reduce impact |
| 1. Climate regulation function | a) EEG (market incentive)<br>b) remuneration for cultivation | a) Federal government<br>b) state, EU | Conversion of grassland into cropland | Single | For instance, extensive grassland on fen soil: very high sensitivity to $CO_2$ emissions if soil is drained or tilled. | P + V: global | Climate regulation function: increase in $CO_2$ (and $N_2O$) emissions in the atmosphere | Transboundary: global (P + V[1]: global) | a) Conservation of permanent grassland<br>b) avoiding tillage for grassland renovation on hydromorphic soils<br>c) rewetting of drained peatlands | a, b, c) individual |
| | | | | Multiple (e.g., S: global) | For instance, extensive grassland on fen soil: very high sensitivity to $CO_2$ emissions if soil is drained or tilled. | | Climate regulation function: increase in $CO_2$ (and $N_2O$) emissions in the atmosphere | Transboundary: global (S, P + V: global) | | |

(continued)

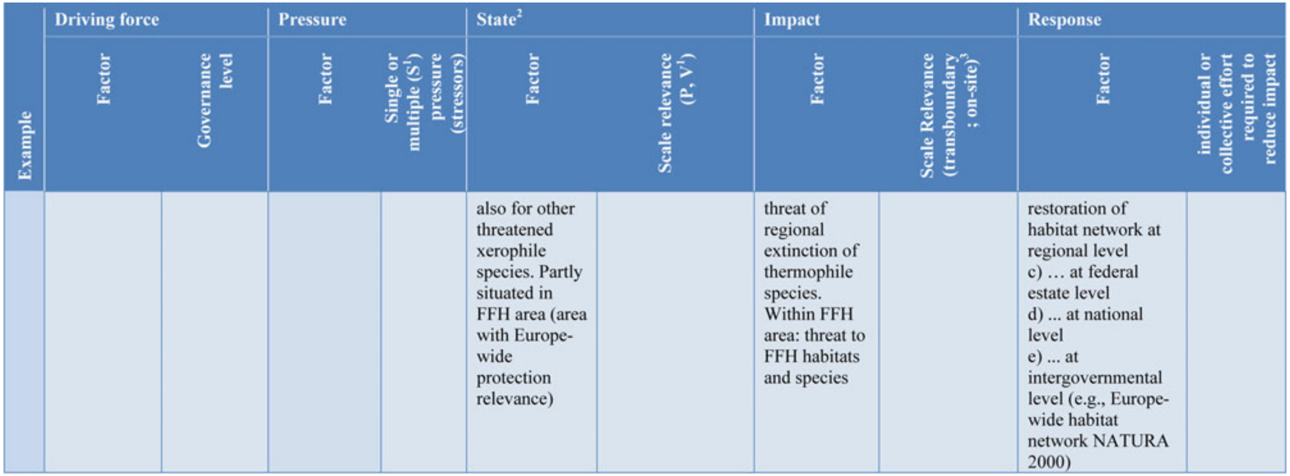
**Table 7.3** (continued)

| Example | Driving force | | Pressure | | State$^2$ | | Impact | | Response | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Factor | Governance level | Factor | Single or multiple (S$^1$) pressure (stressors) | Factor | Scale relevance (P, V$^1$) | Factor | Scale Relevance (transboundary ; on-site)$^3$ | Factor | individual or collective effort required to reduce impact |
| 2. habitat function | | | Intensified land use through expanded biogas crop production (Klein, Fischer & Sandkühler, 2009) | Single | For instance, diverse landscape with different crops, stubble fields, fallows, hedgerows, etc. Red Kite depends on diverse habitat structures: low sensitivity (compared to landscape with fewer but sufficient structures to provide habitat function for Red Kite (*Milvus milvus*)) | P: ~15 km² (hunting ground of Red Kite); V: global | Habitat threat to Red Kite (Milvus milvus) | Transboundary: global (V: global) | a) Cultivation of summer crops (except large-growing crops such as maize, sorghum, etc.)<br>b) conservation and establishment of landscape elements such as stubble fields, field margins, fallows | a, b) individual |
| | | | | Multiple (e.g., S: regional) | | | Habitat function: habitat threat to Red Kite (*Milvus milvus*) | Transboundary: global (S + P regional; V: global) | a) Maintenance of structural diversity within landscape on higher scale through many single measures (cultivation of summer crops, conservation and establishment of landscape elements such as stubble fields, field margins, fallows) | a) collective |

| Example | Driving force | | Pressure | | State[2] | | Impact | | Response | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Factor | Governance level | Factor | Single or multiple ($S^1$) pressure (stressors) | Factor | Scale relevance ($P$, $V^1$) | Factor | Scale Relevance (transboundary ; on-site)[3] | Factor | individual or collective effort required to reduce impact |
| **3. Habitat network function** | | | Shadowing of habitats through cultivation of high-growing biogas crops (e.g., maize, sorghum, etc.) | Single | Low: field margin (length 50 m), element of local habitat network with relevance for *Chorthippus apricarius* (target species for connectivity of field margins in open agricultural landscapes), adjacent field margin has habitat quality | P: conquerable distance ~100 m per day (Schumacher & Mathey, 1998); V: / | Habitat network function for *Chorthippus apricarius*: low threat to habitat function for population at plot level, but no threat to habitat network function for local population | On-site | a) Establishment of field margins, particularly on southern sides of plots with tall cultures<br>b) protection of adjacent field margins and/or establishment of field margins nearby to close gaps in habitat network | a, b) individual |
| | | | | Multiple (e.g., S: regional) | Very high: essential field margins for connectivity maintenance within regional habitat network with relevance for *Chorthippus apricarius*, but | P: > (differ according to species); V: intergovernmental (EU) | Habitat network function (for different xerophile target species): destruction of regional habitat network – | Transboundary: intergovernmental (S: regional; P>;V: intergovernmental | a) Arrangements with farmers of adjacent plots to cultivate lower crops next to tall crops; establishment of broader field margins on southern plot borders.<br>b) protection and establishment/ | a) individual;<br>b-e) collective |

(continued)

**Table 7.3** (continued)



| Example | Driving force |  | Pressure |  | State[2] |  | Impact |  | Response |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Factor | Governance level | Factor | Single or multiple ($S^1$) pressure (stressors) | Factor | Scale relevance ($P, V^1$) | Factor | Scale Relevance (transboundary ; on-site)[3] | Factor | individual or collective effort required to reduce impact |
|  |  |  |  |  | also for other threatened xerophile species. Partly situated in FFH area (area with Europe-wide protection relevance) |  | threat of regional extinction of thermophile species. Within FFH area: threat to FFH habitats and species |  | restoration of habitat network at regional level<br>c) … at federal estate level<br>d) ... at national level<br>e) ... at intergovernmental level (e.g., Europe-wide habitat network NATURA 2000) |  |

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[1] P: process-related scale effect; V: value-related scale effect; S: Space crowding; [2] State = sensitivity and value of a considered natural asset; [3] scale relevance of global, intergovernmental, national, regional, local > above farm level; / not defined)

differ regarding their risk potential for $CO_2$ emissions. Grasslands with hydromorphic and, particularly, organic soils are, for instance, very sensitive to tillage, while non-hydromorphic mineral soils exhibit a much lower risk of GHG emissions due to grassland conversion (Höper 2008, 2009; Janssens et al. 2005). Therefore, a small area of converted grassland can also lead to higher emissions than those of large converted grassland areas if the smaller area exhibits a higher **risk potential** for GHG emissions due to the site conditions (**state, sensitivity**).

Climate warming is caused by multiple individuals causing GHG emissions (space crowding) on a global scale. Thereby, the impact crosses all existing administrative levels (**process-related scale effect**). According to the Kyoto Protocol, the climate regulation function of sinks and reservoirs of GHG gases is a common good of global relevance and should therefore be protected (Art. 2a, ii; United Nations 1998). Thus, the spatial value of this pressure's impact can be considered global, thus automatically crossing different decision-making levels (**value-related scale effect**).

The Kyoto Protocol proposes sustainable forms of agriculture (Art. 2a, iii; United Nations 1998). **Responses** to reduce or prevent GHG emissions due to farm management are the conservation of permanent grassland, avoiding grasslands tillage and rewetting drained peatlands. To stop global warming, the total amount of GHG should be reduced. Since it is irrelevant which source is reduced in which region of the world, each reduction will show an individual mitigation effect. Responses to mitigate GHG due to biogas crop-production-related pressures can thus also be implemented individually (see Table 7.3)

### *7.5.2 Example 2: Habitat Function*

Expanded biogas crop production can impact the main factors that influence the landscape's habitat function for different animal and plant species (Wiehe et al. 2010). An example of the impact of extended biogas crop production on a habitat function is that of the Red Kite (*Milvus milvus*). The extended monocultural cultivation of renewable resources (**pressure**, driven by the renewable resource bonus of the EEG – **driving force**) – particularly maize for biogas and rapeseed for biofuels – is listed as a main threat to the Red Kite population in Lower Saxony (Klein et al. 2009). The Red Kite depends on diverse habitat structures such as diverse crop rotations (including summer crops) and landscape elements such as fallows, grasslands, stubble fields, etc. (Krüger and Wübbenhorst 2009). Where such feeding habitats have been displaced by maize monocultures, the Red Kite can no longer find enough food to survive (Klein et al. 2009).

Besides the **pressure** factor, the real impact on the Red Kite also depends on the **sensitivity** of the affected natural asset (see Table 7.3). The Red Kite's mobility allows it to search for food within a hunting ground of up to 15 $km^2$ (Bayerisches Landesamt für Umwelt 2011; Landesamt für Natur 2010). It can cover a distance between nesting and feeding sites of up to 12 km (Krüger and Wübbenhorst 2009). If this area constitutes a multi-structural landscape with sufficient feeding habitats,

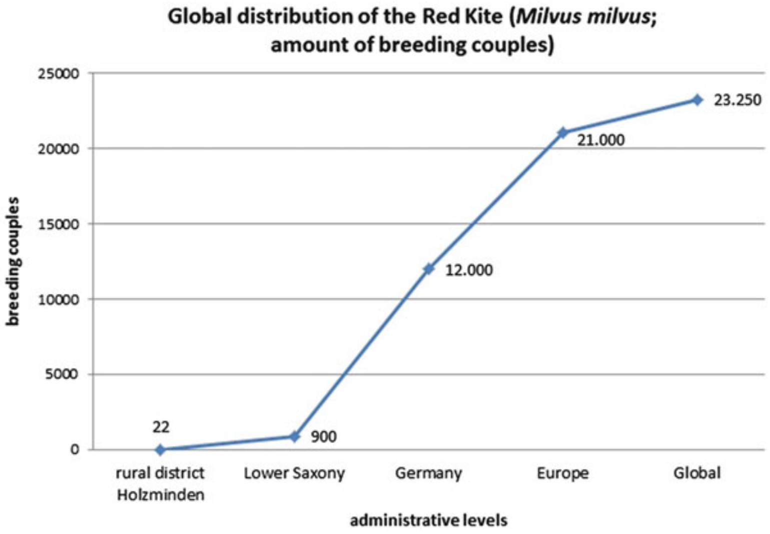

**Fig. 7.2** Responsibility of different administrative levels for the Red Kite (Milvus milvus) population according to its global distribution (Data sources: Südbeck et al. 2007; Bird Life International 2011; Klein et al. 2009; Schmidt 2009)

the **sensitivity** to limited structural changes is relatively low, because many single changes are required to destroy the habitat function. Thus, growing maize on one plot will not significantly affect the Red Kite's food supply. However, this may change if a farmer has a large farm and converts larger parts of the Red Kite's hunting ground into a monocultural and monostructural cropland area, or if many farmers in the region do so (**multiple pressures – space crowding effect**). Since this reduces the food supply (smaller mammals, birds), the habitat function will probably be destroyed and the Red Kite population would be threatened. If the process affected by the pressure exceeds the own spatial decision scope – for example, if the converted farm plots previously constituted important unique feeding habitats for one or more breeding pairs of Red Kite within a broader territory – a **process-related** transboundary impact results from the structural changes.

Over 50 % of the global population of Red Kite resides in Germany (see Fig. 7.2; Bird Life International 2011; Südbeck et al. 2007). Consequently, Germany has a global responsibility to protect this bird species (Südbeck et al. 2007) and should protect it although the Red Kite is common in many German habitat regions. Since the Red Kite is listed as near-threatened on the global Red List and in Annexure I of the European Directive on the Conservation of Wild Birds (Directive 2009/147/EC), expanded monocultural biogas crop cultivation on former or potential Red Kite habitat regions in Germany (**high value**) may impact the global population (**value-related scale effect**). The value of the affected population for the maintenance of local, regional and transregional populations, or for the species as a whole, therefore defines the scale of the impact.

According to the European Directive on the Conservation of Wild Birds (Directive 2009/147/EC), the Red Kite should be protected. Specific conservation areas and measures should therefore be implemented to guarantee its survival and reproduction in its distribution areas (Directive 2009/147/EC). If the impact on the Red Kite is low and caused by single or few pressures, **responses** such as the cultivation of summer crops (other than large-growing crops such as maize, sorghum, etc.) can be applied **on individual farms**. However, if there is a broader spatial impact, it has to be reduced through a **collective response**, since the Red Kite depends on spacious structural diversity in landscapes. This would imply the need for coordination on higher decision tiers. A single farmer's adaptation measures cannot create a connecting, diverse landscape.

### *7.5.3 Example 3: Habitat Network Function*

Large-growing biogas crops, such as maize, sorghum, etc., shade field margins, which are important habitats and habitat network corridors for many xerophile species (Table 7.3). Shading field margins (**pressure**) can impact the habitat network function of xerophile species such as *Chorthippus apricarius* (locust species). *Chorthippus apricarius* has its main distribution in open, extensively used agrarian landscapes. It requires very high summer temperatures and ground exposed to sunlight (Grein 2005), which means its sensitivity to shading is high. This species uses field margins as habitat and as a corridor to migrate to adjacent habitats. If a formerly sunny field margin (e.g., a field of low-growing summer wheat with little shade effect adjacent to a field margin) with a *Chorthippus apricarius* population is shaded by changing the cultivation from low-growing to high-growing (energy) crops (**single pressure**), the population will probably lose this habitat. Since the species can cover a distance of approximately 100 m/day (Schumacher and Mathey 1998) and the affected field margin in the example only is only 50 m long, the population can still migrate to the adjacent field margins provided that their site conditions comply with this species' demand (low **sensitivity**). Thus, the **impact** of one shaded (shorter) field margin on the species existence will probably be low. Pursuant to the example of a single pressure on a German farm, an affected *Chorthippus apricarius* habitat would constitute an on-site impact, because the species has no particular protection status in German law, i.e. there is no **value-related scale effect**. In contrast, the impact on *Chorthippus apricarius* can be higher if many plots in one area have large-growing crops (**multiple pressures, space crowding**). The species has a very short activity radius (approx. 100 m/day, Schumacher and Mathey 1998) and shading the field margins on a broader scale will remove potential migration corridors and habitats. Thus, the affected population cannot migrate to other habitats and may become extinct there (**impact**). Since the impact of the multiple pressure within example 3 (Table 7.3) occurs partly in a flora-and-fauna habitat (FFH) area (NATURA 2000, European protection area; Council Directive 92/43/EEC of 21 May 1992) and FFH areas are affected, the result is a **transboundary impact** of Europe-wide relevance (**value**). Furthermore, the transboundary impact can also result from the pressure level exceeding the different species' activity radius (**process-related scale effect**).

Generally, the higher the number of barriers established in a habitat network, the higher the separative effect (Girvetz et al. 2007; Jaeger et al. 2007) and the smaller the chances of populations crossing over or finding new habitats and, thus, surviving (With and King 1999; Jedicke 1990). The higher the number of network corridors established, the higher the likelihood of species migrating to other habitats and maintaining a habitat network. Thus, if owners of adjacent croplands who cultivate maize and other large-growing biogas crops adjust their crop rotations and reduce their cumulated pressure, this can have a positive **response**. An additional measure to maintain a habitat network can be realised by establishing broader, extensive field margins on plots' unshaded southern sites. This measure can improve local habitat conditions, also on single fields, by providing margins large enough for a viable population (**individual effort**).

## 7.6 Using the DPSIR to Deduce Governance Approaches

Applying the test scheme concerning pressure and impact can help check whether the impacts of biogas crop cultivation can be solved through single-approach, initialising conservation measures on the farm level, or whether upper governmental levels should apply instruments (regulatory, financial, informative or others) to provide incentives (Fig. 7.3).

Individual farmers can prevent or reduce farm-level (on-site) impacts (see Fig. 7.1). Advice from the next administrative level on how to realise good farming practice (GFP) and cross-compliance (CC) standards, or even how to create environmental benefits from biogas crop production related to individual site conditions, can support a farmer. Single approaches can also prevent or reduce impacts if a single pressure causes a transboundary impact (**process** or **value-related scale effect**). On the one hand, measures can target the affected natural asset (spatially targeted) by, for instance, proclaiming protection zones and through agri-environmental measures to conserve a specific common good. On the other hand, they can target the individual producer (spatially untargeted) by making advice on adequate land management available or by imposing fines (e.g., if the GFP is violated). However, if an upper-level value is affected, the total impact on the natural asset or ecosystem service can probably only be detected at this upper level. Under these circumstances, governance institutions from the next level should initiate the prevention or reduction of the pressure source by, for example, organising informational support or consultation for the responsible pressure entity.

Since they are caused by multiple individuals on a broader scale (**space crowding**) (Roots 1988), many unsustainable land management practices' impacts do not become visible on a single plot or farm (Ruschkowski and Wiehe 2008; Wiehe et al. 2009; Foth et al. 2007). If a collective approach is required to solve an

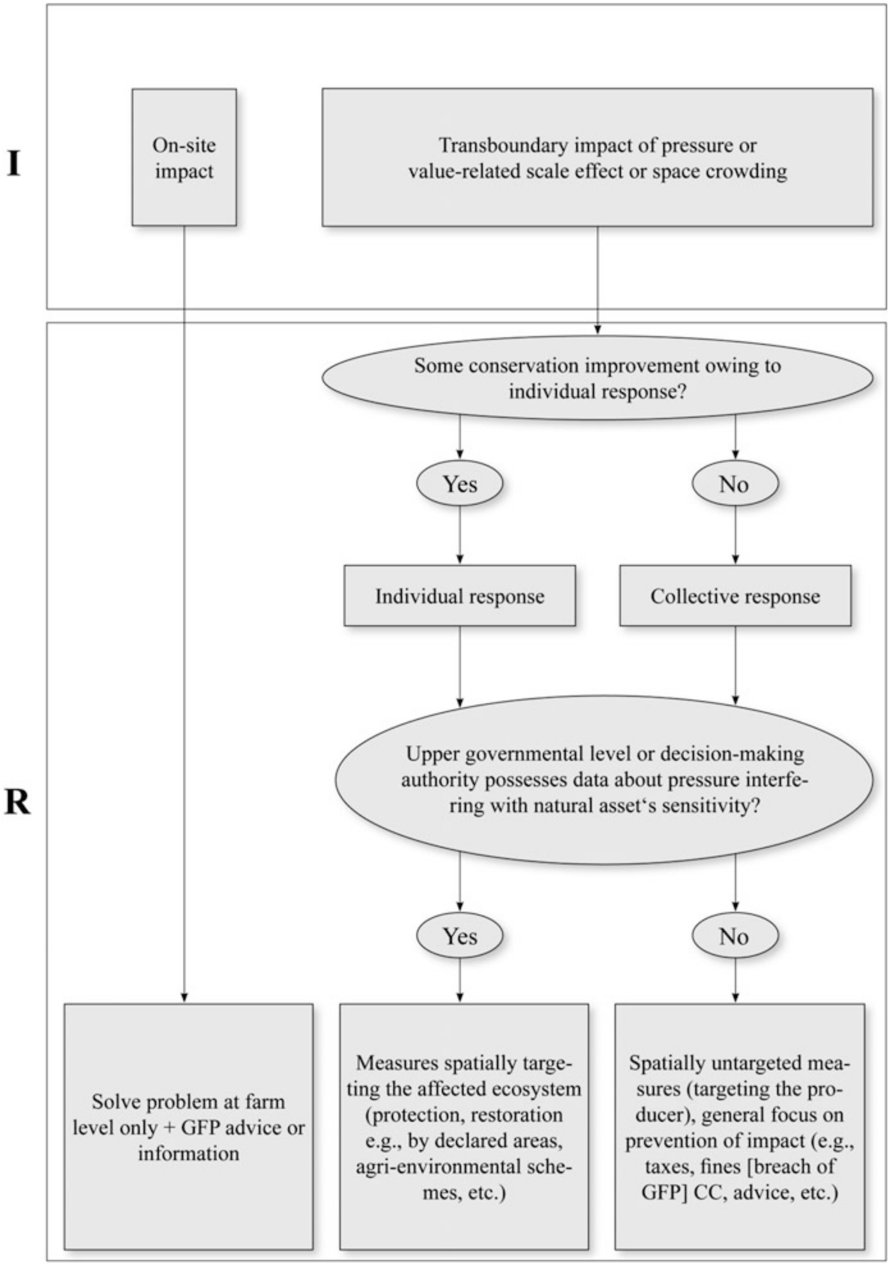

**Fig. 7.3** Scale-related instrumental response approaches

impact, the majority of individuals would have to agree to improve their land management themselves. To conserve the performance and functioning of the ecosystem service for the public, a higher administrative level should supervise this by observing, managing and preventing single sources of potential cumulative (for cumulative effects assessment or CEA, see, e.g., Parker and Cocklin 1993; Dubé 2003; Cooper and Sheate 2004; Noble 2010), value-related or process-related conflicts. Authorities and planning institutions at the level in question should estimate the single and cumulated potential pressures and relate them to spatial sensitivities to assess the risk of potential impacts on the natural assets within their spatial administrative boundaries. Government coordination can help effectively design and arrange the various measures applied, if it provides broader spatial data on the environmental context and ecological demands of single sites. This is required to consider ecological interconnectivities (e.g., the network potential of different habitats). If there are data on the spatial interference of pressure and on the vulnerability of a natural asset/ecosystem service (state), governmental institutions can develop measures that target spatial site conditions (e.g., agri-environmental measures, protection areas, etc.). Spatially untargeted measures will have to be implemented if there are no spatially concrete data on how pressure and state interact. However, spatially untargeted measures, such as taxes, the GFP, etc., can also be implemented in addition to spatially targeted measures.

## 7.7 Scale Relevance of Benefits and Costs

Scale related problems of fit often can be expressed in economic terms. Scale related discrepancies may be cause for beneficiaries of environmental action and those who pay the cost not being identical. As farmers' decisions to apply conservation measures depend very much on the financial costs and benefits of the considered measures (Pannell et al. 2006; Mante and Gerowitt 2006) they need information about costs as well as possible benefits on farm scale. Also they should know about payment schemes for compensation if they are not the beneficiaries of environmental measures themselves. The required information about costs refers to a farmer's expenditure regarding his labour, worker wages, machine running times, fertilisers, other materials, etc., in order to apply a particular measure. Since a conservation measure's costs depend strongly on the site conditions, the cost calculations for the farmer should be site specific. The benefits on farm level may include for example to increase revenue from less productive sites by choosing a new crop which cuts cultivation costs and, for instance, reduces soil erosion. However, often the costs occur at farm level but the benefits occur on other levels and no mechanisms are in place to make beneficiaries pay the farmer for producing these benefits. Also the opposite happens: benefits happen on farm scale and costs have to be paid on higher levels. Farmers may, for example, benefit economically from permanent grassland's conversion into cropland if biogas electricity prices exceed milk prices. However, the costs of the GHG emissions released by this land use change are global due to the impacts of global warming. Mostly, governmental institutions will have to pay them to maintain the supply of ecosystem services. This may be very inefficient if the global compensation cost exceed the expenses for avoiding the impacts on farm level.

Therefore the costs and benefits of conservation measures should also be assessed in the light of their spatial distribution. The farmers need information about cost and benefits on farm scale. The government and the public need information about the amount of expenses for external costs or compensation arising for the public (on higher levels) as well as about benefits produced by farms. Such information is a precondition for taking efficient governance measures

## 7.8 Conclusion

Up to now scale-related problems of fit have been neglected in biogas politics. This chapter proposes methods for analysing these problems on the farm level. The DPSIR scheme has proven a suitable structure for this analysis. If pressure and impact occur on different scales this discrepancy indicates a potential problems of fit. Such a diagnosis allows for analysing or finding response measures in concrete cases as well as judging driving forces and suitable governance schemes.

The proposed assessment scheme for studying the impacts and scale relevance of biogas crop production consists of various lists of possible pressures, impacts and response options as well as the assignment of their possible or general scale relevance. The potential pressures and impacts discussed in this chapter relate mainly to biogas crop production. However, the methodology may also be applied to other agricultural land use sectors. In a concrete case, the impact and scale relevance are assessed in an integrated examination of the pressure and state (value and vulnerability). Supra-farm information about multiple pressures should also be taken into account. The proposed measures (from a general list) can be adapted to conditions of the individual farm. Adequate decision levels and governance strategies for solving problems can then be proposed from a theoretical perspective and are based on the combination of the scale relevance, the number of possible polluters, the spatial allocation and/or the limitation of the impacts. In order to comply with the subsidiarity principle and lead the way to the most efficient governance options, a concept has been developed to explore farms' and farmers' capacities to prevent or reduce their management impacts on their own.

The methodological approach to the assessment as well as the proposal of possible measures should be based on existing research on the impacts of biogas crops. In contrast, the theoretical framing in the context of the scale issue is new, as is the substantiation and adaptation of the DPSIR analysis regarding the scale-related consequences of its different components. This new classification is of great relevance in order to choose the most adequate governance strategy to solve energy plant cultivation problems. However, the assessment concept will have to be tested in future to prove its applicability. Possible difficulties could be data problems, such as missing data regarding multiple pressures. Supra-farm information on multiple pressures will have to be taken from the respective statistical data and scenarios of future development.

In addition, the theoretical approach and the proposed governance strategies will not necessarily always be the most effective way to solve problems. The strategies are based on the general assumption that regulations and decisions should always be taken on the affected (political) tier where the ecological damage and the costs of unsustainable management become clear. While there is a strong logic in this approach and other economic research results point in this direction (e.g., the theory of the tragedy of the commons) (Hardin 1968; Ostrom 1990; National research council, UN 2002), there are also good reasons for assigning as much responsibility as possible to the lowest decision level. A major argument for giving responsibility to the lowest level is that conservation measures are most successful if the individuals affected by conservation measures are involved (i.e. can participate) in the measure implementation process (Schenk et al. 2007). However, successful natural resource management cannot be managed on a single administrative level. Nested systems (see Marshall 2008; Berkes 2002; Ostrom 1990) are required, including the national and local levels and the links between them, as well as the intermediate level (Ministry of Foreign Affairs of Denmark 2007).

An intensive examination of case studies (as outlined in Sect. 7.5) is only a first step in a longer research process that sheds light on the potentials of the farm level to deal with these responsibilities. In future, case studies should lead to better hypotheses regarding the ways in which farmers can be motivated to adopt sustainable management practices and the hindrances along the way. A more extensive quantitatively oriented survey should follow in order to derive results that can be generalised and that can support governance strategies in different contexts and under different preconditions. Nonetheless, in future, it should be possible to adapt such strategies to individual farmers' capacities and willingness. A simplified and adapted version of the outlined survey may be a tool for assessing these individual capacities.

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