International Journal of Environmental Sciences & Natural Resources
ISSN: 2572-1119

Juniper Publishers
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Mini Review
Volume 15 Issue 1 - October 2018
DOI: 10.19080/IJESNR.2018.15.555905

Int J Environ Sci Nat Res

Targeting Land Use Change to Enhance Multiple Environmental Benefits - A Mini Review

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Submission: October 04, 2018; **Published:** October 24, 2018

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Abstract

With the emergence of agriculture, human influence on natural ecosystems has accelerated and intense unsustainable land use is now one of the main factors causing eutrophication of both aquatic and terrestrial ecosystems. Using a holistic approach in agricultural management, as the term "Agroecology" implies, could potentially increase resilience and sustainability of a farming system. With a starting point in a previous published conceptual framework, describing how site-specific modulators can modulate the effect of drivers on human land use, we call attention to a targeted approach in land use change. The targeted approach describes a simple method to achieve multiple environmental benefits when selecting areas to initiate a certain land use change (exemplified with results from two previous studies). We review two main national goals: 1) To lower nitrogen loads by 13,000 t nitrogen/year and 2) achieve five mill ton dry-matter protein from grassland. Results indicate a potential to reach the main goals while simultaneously boosting nature areas and strengthening local environments. In conclusion, applying the targeted approach, or diversions of it, could potentially create multiple environmental benefits while reaching a main national goal.

Keywords: Agroecology; Targeted approach; Land use change; Multiple environmental benefits; Nature; Nitrogen

Introduction

Earth's resources have enabled and maintained human population growth through millennia, first supporting hunters and gatherers and later supporting farmers and herders [1]. With the establishment of permanent agriculture approximately 10,000 years ago [1], human influence increased and has now outpaced the importance of climate as a driver of land cover patterns and dynamics [2,3]. This intensification has led to e.g. eutrophication of both aquatic and terrestrial ecosystems and an overall tendency towards increased fragmentation or complete homogenization of the cultural landscape [4-6] and of small natural and semi-natural areas [7,8]. The existence of such areas is crucial for maintaining high levels of biodiversity [9-12] and for supporting the sustainable provisioning of ecosystem services [13,14] and landscape multifunctionality [14]. Hence, past and present-day research focusing on sustainability should circulate on how to achieve sustainable, and profitable, agriculture while simultaneously maintaining full function of surrounding ecosystems and - multiple environmental benefits. Applying a holistic approach in agricultural management and implement theory form ecology into agronomy could increase resilience and sustainability of a farming system - a term referred to as "Agroecology" [15-17]. Over the last 4 decades, the term "Agroecology" has been manifested not only in science but also as an agricultural practice near the farmer [18], and in light of the increasing human population, attention on how to entangle agriculture and nature conservation is needed to reassure a more sustainable resource use.

Here, we use the Danish region to argue the potential to achieve multiple environmental benefits while changing agricultural practice. We describe a targeted approach to detect areas, which should be the first to undergo a certain land use change (from intense agriculture to set aside [19] and from cereal to grassland [20] based on local environments characteristics and thereby how to strengthen the complete agro-ecological system while taking spatial varying relationships between driver and response into account, as described from the conceptual framework in Odgaard et al. [21].

Results and Discussion

For the Danish region, area scarcity and agricultural nutrient-surplus has been put forward as two of the main threats towards biodiversity and nature persistence [22], and Denmark has a national goal to reduce coastal N loads by 13,000 t nitrogen (N)/year [23]. At the same time, promising methods to derive protein from grass, as a substitute for protein derived from soya imported from the tropics, encourage methods to identify where to grow this new grassland [24]. Hence, the two main goals assessed in this review are:

a) To lower N loads by 13,000 t N/year and

b) Achieve five mill ton dry-matter protein form grassland.

We adopt the framework described in Odgaard et al. [21] to increase attention on how to gain environmental benefits from land-use change due to spatial variations in local environmental

variables using a targeted approach. The framework [21] consists of three parts: 1) the effects of geophysical constraints and socio-technical drives on land use (part 1), how this effect is shaped by site-specific modulators (part 2), and eventually causing direct land use and new land cover patterns (part 3). Here, we only focus on the socio-technical drives in the framework.

The targeted approach

The targeted approach developed in Odgaard et al. [19] illustrates how a national goal describing quantities can be achieved while obtaining both agricultural optimizing and multiple environmental benefits. The approach is rather simple and easy applicable to other regions with the sufficient amount of geographical data. The method function on a dataset where each row describes the smallest area unit e.g. watersheds, municipalities, or fields. Each unit should hold information (attributes) on how much of the national goal is reached by conducting a specific land use change, and a quantitative measure of the environmental benefit/s following this change. The national goal-value is summed in a stepwise manner, counting the unit with the highest environmental benefit first, until the goal is reached. The number of units to undergo a certain land use change can be visualized in geographic information systems and local landscape characteristics can be calculated depending on available data.

Application of the targeted method

Two previous studies from the Danish region have highlighted potential benefits from using the targeted approach to initiate land use change: one considering where to initiate set aside with the main purpose being N mitigation while gaining natural and sociotechnical benefits [19], and another considering where to initiate grassland production with the main purpose to produce protein dry-matter while gaining environmental and natural benefits [20] (Figure 1).

In the first study [19], farmland to set aside were selected by targeting for areas with a high coastal N load, amount of surrounding nature, and soil value. Results indicate, contrary the expectation, that it is cheaper to target for surrounding nature compared to soil value due to changes in affected area-size. Furthermore, multiple benefits can be achieved when targeting set-aside for a variable describing a combination of N load, nature and soil value, if willing to convert 4 % more land. In the other study from the same region [20], the rational was to increase local grassland-production and thereby decrease import of protein derived from soya, which is a rather unstable process [25,26]. Results reveal that up to 60% (7.800ton N/year) of the national N reduction goal can be reached by targeting conversion of cereal to grassland production towards areas whit highest N load. Simultaneously, grasslands over cereals can benefit local nature areas by boosting surrounding nature since grasslands are more extensively managed resulting in a higher biodiversity value than cereals [27]. Hence, national goals to lower N or boost existing nature can affect how humans decide to utilize the land and this effect can be modulated by site specific N loads, soil values, or amount of surrounding nature (Figure 1).

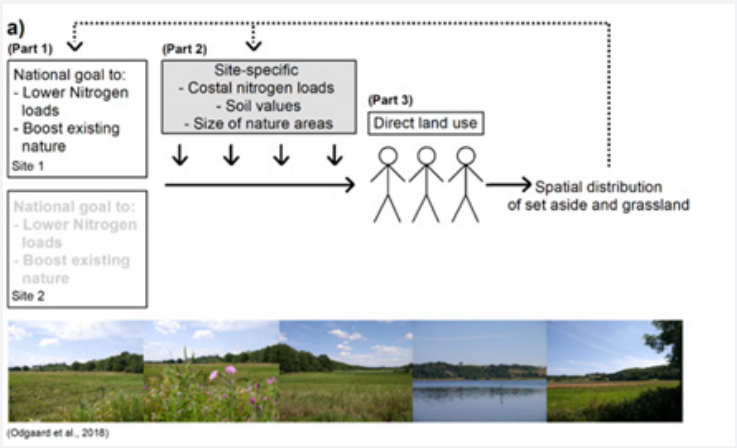

Figure 1: Conceptual framework as from Odgaard [22] exemplified with results from Odgaard [20,21]. The effect of the sociotechnical drivers (described as the two national goals: 1) to lower coastal nitrogen (N) loads by 13,000 ton N/yr and 2) boost existing nature areas) on land use (part 1) is shaped by site specific modulators (described as costal N loads and size of nature areas) (part 2) causing spatial distribution of land cover patterns (described as converting from agricultural land to set aside or from cereal production to grasslands (part 3). Bold text indicates high importance in a site and grey text indicate low importance in a site. Pictures are of a typical Danish lowland agricultural landscape describing set aside, grasslands, forest and fjords (Mette Vestergaard Odgaard [23].

Conclusion

Diverse demands for natural resources increase attention on how to create and sustain multifunctional landscapes. We describe a targeted approach to include other factors than the main purpose when shifting land use practice. Increased understanding of the factors that shape land-cover patterns could potentially help build a more sustainable agricultural system [28], which is a central issue for landscape ecology, biodiversity conservation, landscape planning, and studies in food production and human food security. Implying the targeted

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approach enables evaluation of possible costs and benefits - both environmental and social - resulting from certain land use change prior to the actual conversion.

Acknowledgement

Thanks to support from Innovation Fund Denmark via the dNmark.org Research Alliance, and the EU Commission funded NitroPortugal, H2020-TWINN-2015 coordination and support action n. 692331.

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