Biodiversity that Mitigates Pests in Agroecosystems

Expert review by:

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Managaing Agricultural Resources for Biodiversity Conservation:

A Guide to Best Practices

Abstract

The ecosystem service context permits a comprehensive assessment of the mitigating effect of biodiversity on pests. Indicators can be defined, and advantages as well as possible trade-offs, with economic incentives, can be recognized. The diversification of plants at the levels of the field, farm, and beyond is a widely used method for increasing biodiversity and mitigation of pests. However, uncertainties should be evaluated and risk management strategies formulated. The judicious use of pesticides is an important contribution to conserve natural enemies and to enhance their effects

There is a need to complement the existing literature with additional studies. An enormous pay off could result from further research in the characterization (biophysical and economic) of ecosystem services and in the development of institutions for their safeguarding the implicit use of biodiversity in pest control (Daily & Dasgupta, 2001).

Introduction

Pests are considered as any of the various organisms such as fungi, insects, rodents and plants, that harm crop or livestock or otherwise interfere with the well being of human beings (Anonym, 1996). According to the World Health Organization (WHO), good health is the state of complete physical, mental, and social well being. Accordingly, pests as well as their biological control agents operate in many different areas relevant to human health. In fact, the interference with human well being may occur in several subsystems within a general human health system (Baumgärtner *et al*., 2001). For example, biological agents may mitigate pests in crop subsystems, livestock subsystems, infectious disease subsystems as well as in food and feed storage subsystems. To deal with pests in a broadly defined human health context, an ecosystem approach with emphasis on ecosystem services is appropriate (Daily, 1997). Ecosystem services are the wide array of conditions and processes through which ecosystems, and their biodiversity, confer benefits to humanity; these include the production of goods, life support functions, life fulfilling conditions, and preservation of options (Daily & Dasgupta, 2001).

Swingland (2001) points out that biodiversity does not have an universally agreed on definition and is often re-defined on each occasion according to the context and the purpose of the author. According to the International Convention on Biological Diversity, biological diversity means the variability of among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems of which they are part; this includes diversity within species, between species and of ecosystems. The term ‘biodiversit thus refers to the variety of all life on earth, and explicitly recognizes how the interaction of the different components of ecosystems results in the provision of essential ecosystems services on the one hand, and on social and recreational opportunities on the other, including being a source of inspiration and cultural identity (OECD, 2001). Biodiversity, as its relates to agriculture, can be considered in terms of genetic (within species), species diversity (between species) and ecosystem diversity (of ecosystems).

Biological control is the use of parasitoid, predator, pathogen, antagonist or competitor populations to suppress a pest population, making it less abundant and thus less damaging than it would otherwise be (Van Driesche & Bellows, 1996). The principle methods are the introduction of exotic natural enemies, inoculative and inundative releases of natural enemies, and conservation of natural enemies. However, biodiversity that mitigates pests does not fully correspond to biological control for several reasons. For example, we argue that the release of mass reared natural enemies, even when originating from the same geographical area, may not be considered as biodiversity utilization. Moreover, the scope of traditional biological control is often restricted to pests of goods and does not necessarily cover pest mitigation in an ecosystem service context.

The purpose of this paper is first to provide some background information on current ecological knowledge relevant to the development of a guide to best practice in conservation of agrobiodiversity, of which biodiversity mitigating pests is one. The relatively advanced knowledge on structure and function of crop subsystems enables us to identify some principles that can be transferred to other subsystems, such as those relevant to human health. The workshop recommendations and the information obtained from reviewers are summarized in the next two sections. Both recommendations and relevant elements of national planning documents and policy papers are compared and related to the ecological background information.

Background information on mitigating effect of biodiversity on pests

The work of Risch *et al*. (1983) is a useful entry point for discussing biodiversity effects on pest occurrence. Among the 150 published papers on this subject, they found that in 53% of the cases plant pest density was decreased in diversified systems, in 18% pest density increased, in 20% a varied response was observed, and no change was observed in 8% of the analysed cases. The mitigating effect of biodiversity appeared to be caused by herbivore response to diversification rather than by enhanced natural enemy activity. They, furthermore, noted that the information base generally did not allow the identification of ecological mechanisms relevant for assessing the effects of agricultural diversification on pests. Nevertheless, many applied ecologists turned their attention to plant diversification in their attempt to increase biodiversity and decrease pest impact (Altieri *et al*, 1991). As stressed in a Swiss strategic planning document, (Anonym, 1989) an increase in plant biodiversity is accompanied by an increase in the biodiversity of other taxa such as arthropods.

Since the pioneering work of Risch *et al*. (1983) a great number of studies have been conducted to elucidate some of the issues raised above. Nevertheless, some ecologists still argue that influence of changes in biodiversity on ecosystem functioning remains highly controversial (Morin & Zamora, 2001), while others stress that it may constrain short term productivity though it may be a help to assure against complete disasters (Burton *et al*., 1992). Nevertheless, maintaining biodiversity is important because we cannot always identify which species are critical, or which species are important in the future (Burton *et al*., 1992).

The temporal dynamics of physiologically structured populations has recently been reviewed by Di Cola *et al*. (1999). Multitrophic population interactions have been analysed by Gutierrez *et al*. (1984) and discussed in the context of bottom-up and top-down population regulation (Gutierrez *et al*., 1994) and more general, in the context of food web dynamics (Berryman *et al.*, 1995b). The importance of indirect effects by predation on prey assemblages has become a major issue in ecology and experimental work is undertaken to test the relevant hypotheises (Spiller & Schoener, 2001). Turchin & Batzli (2001) studied multitrophic interactions involving mammal populations and reviewed, as done previously in Berryman *et al*. (1995a), the methodology used for modelling population interactions. Considerable progress has also been made in modelling the spatial dynamics of populations, both in the areas of mathematical model development (Renshaw, 1991) and of geographic information technology supported statistical analyses (see Schiarretta *et al*., 2001). Hence, the understanding of ecosystem structure and function has considerably been improved in the past two decades and the new insights obtained in ecosystem processes may provide additional elements into strategic planning and policy documents.

Uncertainty describes the condition whereby managers have a lack of knowledge of biodiversity that prevents them from defining the best course of management action (Comiskey *et al*., 1999). For example, Roux & Baumgärtner (1998) found a high uncertainty in the effect of a predator community on Potato Tuber Worm, *Phthorymaea operculella*, eggs in Tunesian rustic shelters. To reduce the risk of unacceptably high potato infestations, they recommended a dosed application of virus. In general, uncertainties can be addressed by adaptive management, that is a systematic, cyclical process for continually improving management policies and practices based on lessons learned from operational activities Comiskey *et al*., (1999).

The conservation of within species or genetic biodiversity is addressed in other components of this initiative, and described elsewhere (Jarvis *et al*, 2000). The above biodiversity definitions (OECD, 2001) focus on taxonomic diversity, i.e. the number and the relative importance of species in a community (Moore, 2001). From a practical standpoint, the assessment and utilization of biodiversity would be facilitated if functional groups rather then individual species can be addressed. However, the authors of recent analyses of a spider and a carabid community concluded that, when working on the community level, important patterns are lost and species-specific information is necessary to predict habitat and seasonal distributions of ground dwelling spiders in grassland ecosystems (Weeks & Holtzer, 2000). Both the OECD (2001) definition and the work of Weeks & Holtzer (2000) stress the importance of species as units. It is noteworthy, however, that the concept of species is difficult to apply over large geographical and geological time scales: Mallet (2001) recommends that conservation and legislation should recognize that living, evolving populations form fractal continua over time and space, rather than attempting a division into spurious ‘fundamental’ units.

Ecosystems may be defined at the field, farm, community level or beyond. Spatial scale denotes the resolution within the range of the measured quantity (Schneider, 1994) and is important when assessing and utilizing biodiversity effects. Moreover, as a continuous habitat continues to be fragmented, it is critical to understand which processes drive changes in the biodiversity of fragmented landscapes (Davies *at al.,* 2001). Landscape ecology is rapidly emerging as a motive force, both in the domain of theoretical ecology and in applied fields such as biodiversity conservation planning (Sanderson & Harris, 2000).

Rather than exclusively dealing with field or farm specific programs comprehensive resource management schemes, involving communities, should be considered when addressing biodiversity effects on pests in an ecosystem service context. It may be of interest to policy makers that eight design criteria have been identified in governing sustainable agricultural systems (Becker & Ostrom, 1995) and successfully being used in species conservation programs (Baumgärtner & Hartmann, 2000, 2001). Policy makers are also reminded that, when infrastructure and markets develop, the need for a broad range of products and services decreases (Robertson & Harwood, 2001). When the costs of adverse environmental impacts are not internalized, or when farmers are not rewarded for ecosystem services that their farms provide to the community or region, they do not include such values into their farm enterprise unless they are motivated and willing to make an altruistic contribution. With continued market evolution, farmers may be increasingly compensated for the full range of ecosystem services as well as actual product output they provide (Robertson & Harwood, 2001).

Recommendations for the Guide to Best Practices: Managing Agricultural Resources for Biodiversity Conservation

Principles. The mitigating effects of biodiversity on pests should be addressed in the broad context of ecosystem services (Daily, 1997) and human health improvement (Baumgärtner *et al.*, 2001) rather than as a reduction of pest induced losses in ecosystems goods only. Consequently, the objectives of ecosystem management are the optimisation of sustainability, the minimization of risks and the maximization of ecosystem services. Ecosystem management must address the whole system rather than individual subsystems. Costs and benefits of ecosystem services, including the production of goods, need to be identified and eventually distributed on the basis of careful assessment of possible trade-offs, with economic incentives being recognized as one tool. The assessment of risks over time, relative dependence, and sustainable livelihoods are critical issues for agricultural biodiversity, and need to be in appropriate balance.

Appropriate practices and good models. Among them is the promotion of plant biodiversity including mixed cropping systems to increase within-field biodiversity. In addition, spatial differentiation, diverse landscapes, and intermediate disturbance areas should be promoted to increase local and regional biodiversity. As stressed in the principles, the costs and benefits of mitigation strategies involving crop management practices, habitat boundaries and integrated pest management need to be assessed.

Tools: Interdisciplinary task forces should be formed to evaluate national research agendas and to develop guidelines for decision making at the farm, community and national level. The terms of references of the task forces should include the identification of indicators and the development of techniques for comparing the costs and benefits of ecosystem services under different management schemes.

Indicators. Among them is the decrease of pest abundance interfering with processes that negatively affect ecosystem services, and the reduced need for interventions. Among the pests, the workshop also recommends to monitor human disease vectors and infectious disease incidence. The indicators are ecosystem specific and should be studied at benchmark sites. Moreover, indicators need to be followed through time and space and related to ecosystem stability, resilience and to risk management strategies. The presence of key groups of natural enemies could also be used as indicator. The monitoring of natural enemy effects via antagonists-prey ratios has been proven to be very effective (Nyrop & van der Werf, 1994). Additional measurable indicators are ecosystem goods and services including suppression of human disease vectors.

Policy. The guidelines should be included in national planning and policy documents, become part of training programs and educational curricula, and should be implemented by decision makers at the levels of the farm, community and the country. The value of ecosystem service should be incorporated into national accounts

Concluding remarks

The mitigating effect of biodiversity on pests can comprehensively be assessed in the ecosystem service context. Indicators can be defined, and advantages as well as possible trade-offs, with economic incentives, can be recognized. The diversification of plants at the levels of the field, farm, and beyond is a widely used method for increasing biodiversity and mitigation of pests. However, the method should be assessed in the framework of landscape ecology. Moreover, uncertainties should be evaluated and risk management strategies formulated. While the diversification of biodiversity through additional plants receives much attention, little reference is made to antagonists of pests. The judicious use of pesticides is an important contribution to conserve natural enemies and enhance their effects. Experts will be able to put specific examples from the biological control literature into the planning documents.

There is a need to complement the existing literature with additional studies. An enormous pay off could result from further research in the characterization (biophysical and economic) of ecosystem services and in the development of institutions for their safeguarding (Daily & Dasgupta, 2001).

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