

Agriculture and Pollinator Biodiversity

Subjects: Biodiversity Conservation

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Pollinator biodiversity is greatly affected by industrialized agriculture practices. Agroecological alternatives for food production must be implemented.

Keywords: agroecology ; sacrifice zones ; Apoidea ; water deficit ; pesticides ; Food sovereignty ; food security

1. Introduction

Industrial agriculture (hereafter “IA”) promoted by the Green Revolution has arguably brought about significant increases in food production globally over the past 70 years ^[1]. These models involve the use of a «technical package» with strong dependency on fossil fuels, which include large-scale monocrop landscapes of improved/selected seeds, increased mechanization, and the incorporation of “external inputs” to enhance plant growth and yield such as the introduction of managed pollinators, synthetic fertilizers and pesticides ^[2].

Agroecology (AE) takes advantage of local biotic components and abiotic conditions found in the agricultural landscape, seeking to match crops with local abiotic conditions and promote beneficial associated organisms ^[3]; highlighting the value of local knowledge and biodiversity that benefits agricultural production ^[4]. For instance, AE considers available organisms that improve crop productivity such as pollination, biological control, and decomposition as “resource biota” ^[5] ^[6]. Through this lens, local diversity is regarded as a natural “internal input” (Figure 1; Figure 2), as opposed to “external inputs” required for IA production, enhancing sustainable food production in agroecologically-managed fields. Internal input provides different ecosystem services and ecological interactions ^[7] ^[8]. The latter includes pollinators, predators, parasites, and herbivores as well as non-crop vegetation, soil invertebrates, and microorganisms, among other components of local biodiversity helping crop yield ^[9].

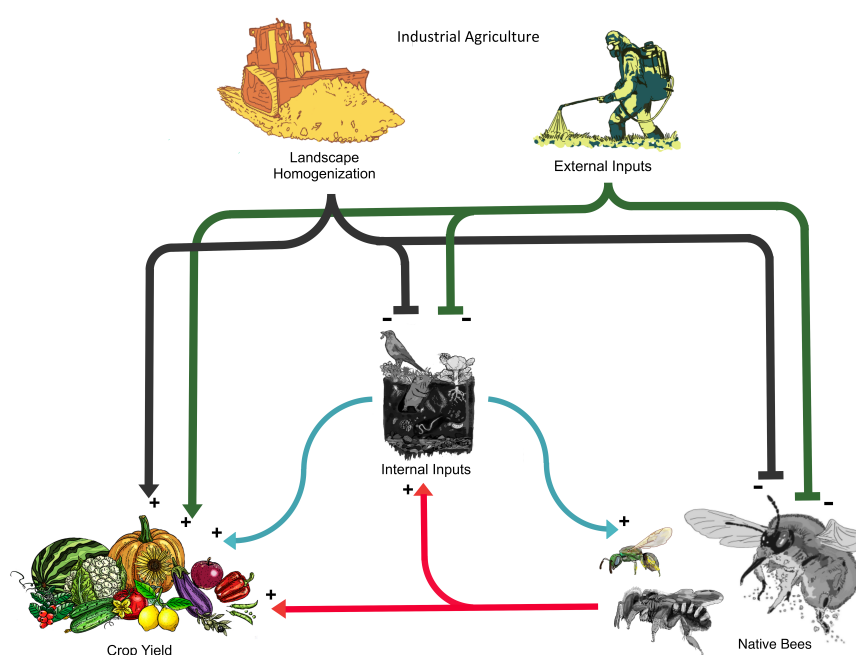


Figure 1. Schematic representation of

industrial agriculture intensive management. Arrows and positive signs represent favorable influences between elements depicted by icons and titles. “T” ending lines and negative signs symbolize unfavorable impacts. *Landscape homogenization*, the simplification of rural ecosystems that takes place under industrial agriculture, is illustrated with a bulldozer. The application of *external inputs* such as pesticides, GMOs, and managed exotic biological control agents and pollinators, is shown as an operator spraying agrochemicals. Landscape homogenization and external inputs are used to sustain *crop yield* production (represented by various fruits) under industrialized schemes. Nonetheless industrial agriculture’s *landscape homogenization* and *external inputs* are at the same time causing a decline of local biodiversity

(e.g., beneficial microorganisms, plants, and animals), which despite not being recognized by industrial agriculture, are contributing to crop yield as *internal inputs* (in calypso lines). This component is illustrated by a slide of soil showing different wild lifeforms and their positive influences by calypso color lines. Among beneficial organisms present in agricultural landscapes are wild pollinators, represented by *native bees*. These are being exemplified in this figure by three specimens (with large to small species) by genera: *Bombus*, *Anthidium*, and *Lasioglossum* native species. Native bees' positive interactions with crop yield and the remaining internal inputs the other components of this diagram are shown with red lines and arrows. Images in grey highlight detrimental effects on illustrated components (e.g., internal inputs and native bees).

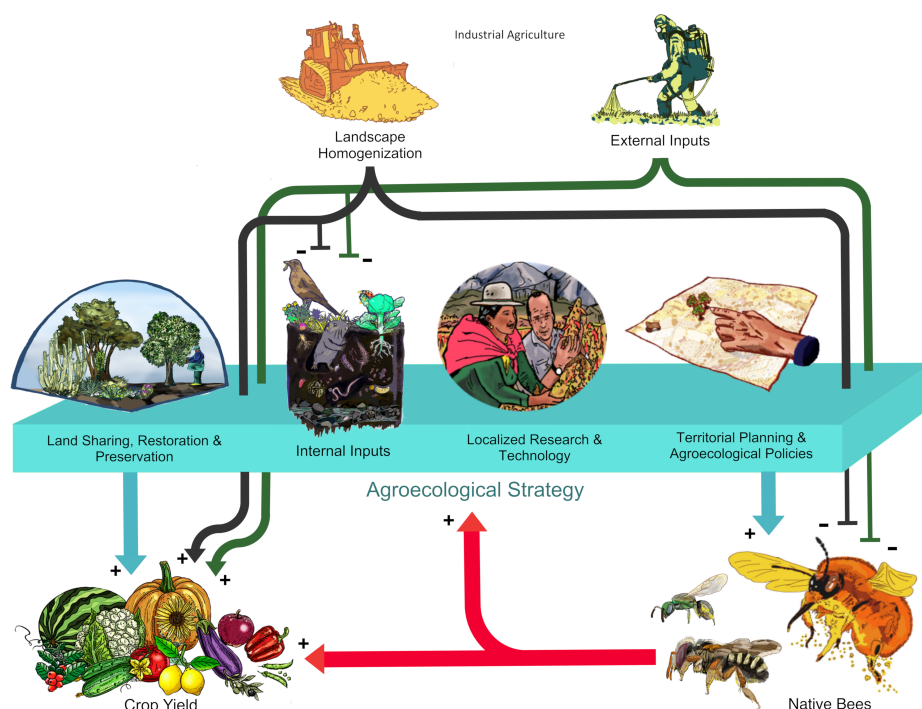


Figure 2. An agroecological strategy (in calypso) to counteract the effects of *industrial agriculture* managements currently in use for food production at world biodiversity hotspots. This plan is based on four main pillars: (i) *Land sharing, restoration and preservation* (illustrated by a wild plant community along a fruit orchard), (ii) the conservation and promotion of *internal inputs*, (iii) the recovery and development of *localized research and technology* (depicted by a local farmer and a scientist exchanging knowledges), as well as the implementation of (iv) *territorial planning and agroecological policies* (illustrated by a farm area map and pointing hand). We propose that these agroecological pillars may contribute to the survival and performance of native pollinators such as *native bees*. These wild pollinators contribute directly to crop yield as well as indirectly by its influences on the agroecological strategy. We suggest agroecological strategy may be able to buffer current LH and EE from IA, as a start point towards a gradual change towards the implementation of an agroecological food production system; not focused on international market needs only, but on food sovereignty and safety as the base for a true global sustainable food production. Illustrations by Cristian Villagra.

2. Protecting Pollination: Strategies for the Future

Human practices, including agriculture, need to return within the limits that keep our planet habitable ^{[10][11]}, for the sake of our own species and all living organisms ^{[12][13]}. Countries with invaluable biodiversity need to rethink critically the way they are doing agriculture and reevaluate local and native sustainable practices ^{[14][15]}. Understanding that native pollinator species are unique “resource biota” (see Glossary already contributing to current crop yield is to be aware of a strategic advantage compared to agriculture food production in non-WBH regions. Native pollinators are part of AE internal inputs that cannot be replaced by IA technological packages or external inputs ^[16]. Coexisting with our threatened local biodiversity (i.e., internal inputs) and valuing its cultural and biological wealth within productive ecosystems will protect the future of pollination services as well as contribute to food security and sovereignty. Here we focus on the development of an agriculture schemes in WBHs considering native biodiversity, and compile a strategy summarized in four pillars based on agroecological thinking as well as First Nations’ knowledge: (1) sharing, restoring and protecting the land; (2) local biodiversity as fundamental AE internal inputs contributing to sustainable agriculture food production and pollinator protection; (3) the need for recovering local knowledges and developing localized research and technology; and (4) territorial planning and the implementation of AE policies (Figure 2).

2.1. Sharing, Restoring, and Protecting the Land

Natural ecosystems are far from simple, and to achieve sustainable agriculture there is a need to maintain their complexity [8]. Polycultures and florally diverse environments have been found to support native pollinator diversity due to a continuous supply of food resources [17]. Agricultural practices need to consider that pollinator functional diversity relies on these native habitats and that biodiversity hotspots by definition are already threatened, thus need to be considered with special care when conducting productive and extractive activities. A sustainable complex landscape matrix is needed to protect hotspots and ensure the delivery of pollination services to crops. This pillar should integrate restoration and protection of large areas of natural habitat and restoration of native land patches within agroecosystems to increase habitat quality (i.e., land sharing) [18]. Pollination services delivered by native insects have been shown to rely strongly on their proximity to natural habitats [19][20][21]. Protected natural areas host higher biodiversity [22] but are not enough to sustain ecological stability [23]. To achieve stability, habitats that have been altered by human activities, including urban zones and areas utilized for productive activities, need to be restored as much as possible [24], leading to effective conservation outcomes by assessing their coverage (i.e., the number and types of species included within their limits) and management [25]. Restoring native patches of anthropized land improves habitat quality within agroecosystems, maintaining and securing native insects [26]. Native patches buffer the negative effects of pesticide application on pollinators [27][28], offer greater flower diversity and nesting sites [29] and are correlated with higher pollinator density [30]. In farmlands these patches also serve as wildlife corridors [31][32][33][34][35], promoting heterogeneous landscapes [36] and stabilizing crop pollination [37]. These patches could be implemented at field edges and should have mixed native plants with partial overlap in floral phenology to provide resources for bees during the whole flowering season [29]. Pollinators benefit from florally diverse environments due to a continuous supply of food resources [17], which are critical for ensuring their reproduction [38]. The size of these patches could be dependent on the crop type that they surround, and research should be carried out to define the appropriate cost-effective sizes within specific agroecosystems [39][40].

2.2. AE Internal Inputs for Sustainability and Pollinator Protection

Among the core principles of AE science and practice is the preservation and use of local diversity as natural inputs contributing to crop yield [41]. This approach also advocates for food sovereignty while reducing the negative effects of agriculture on the environment and society [42]. Monocultures, organic or not, reduce the functional diversity of pollinators [43]. Under an agroecological strategy (AES), biodiversity is incorporated into agroecosystems to mimic natural ecological processes [44] (Figure 2). With higher biodiversity, agroecosystem inner complexity grows and reduces the dependence of crops on destructive external inputs, allowing the system to maintain its own soil fertility, productivity, and protect itself from pests [45], benefiting insects and attracting pollinators [39]. All this allows native pollinators to visit crops safely and thrive in an agroecosystem with food and nesting resources free of pesticides. This higher pollinator biodiversity could even reduce the need to incorporate large numbers of managed pollinators within crops as additional external input. Nonetheless, this falls short of defining AE, as not only are academic, political, and cultural perspectives tightly knitted to this model, AE places small farmers and local knowledge as the key for food sovereignty [46] and does not agree with the new Green Revolution approach, which seeks to perpetuate an IA system for food production [47]. Instead, AE focuses on the dissemination of knowledge from farmer to farmer based on their historical backgrounds and on reviving their ancestral farming roots [48], strengthening communities and allowing them to become autonomous, securing local food production [47]. Mexican and Bolivian farmers are examples of how traditional low-intensity agriculture allows native bee species to provide successful pollination service [49][50]. There is no need for a new Green Revolution, as social vulnerability and income inequities are the main cause of hunger [51]. AES, summarized in this review, aim to protect pollinators not only by its effects in agroecosystems, but also by reducing poverty and improving people's livelihoods, by both recovering local knowledges and developing local research technologies as well as implementing territorial planning and AE policies considering the needs of local communities (explained further in following sections, Figure 2) [52]. People can only protect or be concerned about biodiversity and its conservation once their basic needs have been met. Thus, the world does not need more food commodities to be traded globally; it needs equal access to nutritive food and production not focused only on market and profits [53][54].

2.3. Localized Research and Technology

IA is leading a steady biodiversity decline and exceeding the planetary boundaries that allow humans to survive on Earth [10]. The IA production and market scheme keeps low-income WBH countries of the world relying on the import of technological packages and depending on globalized markets to achieve their productivity goals. Technological packages should not be imported without knowing their consequences to ecosystems, local communities, and economies [55][56]. Critical knowledge gaps still exist regarding taxonomy, ecosystem services, and socio-ecological vulnerability in order to

implement production alternatives considering native pollinators ^[57]. This is especially urgent in WBH countries risking their biodiversity, food sovereignty, and human wellbeing ^[58].

2.4. Territorial Planning and AE Policies

World biodiversity hotspots are strongly threatened by the loss of their species and resource depletion (e.g., water scarcity) due to IA business, currently representing sacrifice zones that provide food and goods to global markets, so the developed side of the world can “go green” ^[59]. This needs to change. AE’s local biodiversity “internal inputs” such as native pollination services ^[60] cannot be labeled as commodities (e.g., “natural capital” ^[60]), as its “exchange” threatens the sustainability of food production and commerce⁴. This is likely currently happening in a “Centinelan” pollination consumption (not a “trade”), as native bees cannot be replaced or recovered once species go extinct. Moreover, there is not a fair planetary-level exchange and interdependency between WBH exporters and international food commerce, as the resulting benefits have been demonstrated to be distributed globally in a both socially and economically unequal way ^[61]. For instance, in Chile IA is coupled with sustained social inequalities and unrest, local communities driven to unsanitary water deficit and unique biomes shrinking as IA expands, leading pollinating species to decline before having a chance to be studied ^{[62][63][64]}. These are the challenges policy makers need to face; if we want to keep the remaining biodiversity of native pollinators in food-producing countries, intensive industrialized agriculture schemes must be first buffered by AES and gradually replaced by true sustainable food production ^{[65][66]}.

3. Conclusions

A new deal considering AE approaches must be implemented globally, considering WBH as key areas both for the preservation of native pollinator biodiversity and rights and wellbeing of local communities. The implementation of agroecological strategies in WBHs as starting point and buffer for IA may facilitate the transition towards a true sustainable food production. AES will improve our understanding of ecological dynamics in agroecosystems, allowing sustainable development over time, ensuring local development and food sovereignty of WBH, for the sake of keeping native pollinator biodiversity and the wellbeing of the whole planet ^{[67][10]}.

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