Crimson Publishers
Wings to the Research

Review Article

From Thai to Zai: Insects as Example of Threatened Nature-Based Solutions for Sustainable Food Production

Jouquet P[1]*, Muon R[2], Traoré S[3] and Harit A[4]

[1]Institute of Ecology and Environmental Sciences of Paris (UMR iEES Paris), Institut de Recherche pour le Développement (IRD), Sorbonne University (SU), INRAe, UPEC, CNRS, Paris, France

[2]WAE Research Unit, Institute of Technology of Cambodia, Cambodia

[3]Life and Earth Sciences Training and Research Unit, Nazi Boni University, Burkina Faso

[4]Department of Zoology, Faculty of Science, Kalinga University, Naya Raipur, Chhattisgarh, India

ISSN: 2770-6745

***Corresponding author:** Pascal Jouquet, Sorbonne University, Institute of Ecology and Environmental Sciences, IEES, FEST, Paris, France

Submission: March 14, 2022
Published: April 14, 2023

Volume 3 - Issue 4

How to cite this article: Jouquet P*, Muon R, Traoré S and Harit A. From Thai to Zai: Insects as Example of Threatened Nature-Based Solutions for Sustainable Food Production. Biodiversity Online J. 3(4). BOJ. 000566. 2023.
DOI: 10.31031/BOJ.2023.03.000566

Abstract

Insects constitute most of the biodiversity on earth and they provide a large range of services to our society. Unfortunately, this biodiversity is threatened by human activities such as the destruction of natural habitats and urbanization. This article assesses advances in our knowledge of the impact of insects on sustainable food production in low-income countries. It focuses on two research topics that have emerged in recent years: entomophagy and the creation of small household farms where insects can be reared and later sold (i.e., the Thai example) and their utilization for improving soil fertility and availability to plants (i.e., the Zai example). The article advocates for considering of the diversity of solutions and adaptations that have been found in nature. The utilization of natural resources by local communities or ethnic groups can be vast and should be seen as a source of inspiration for scientists to develop sustainable food systems.

Keywords: Biodiversity; Entomophagy; Food security; Ecosystem services

Introduction

Our societies must face many dramatic environmental challenges, some of which are directly linked with the way we produce and consume or indirectly with the climate change and its consequences on ecosystems and the preservation of biodiversity [1,2]. Tropical and subtropical regions are on the front line of this battle because they host most of the human population and most of the biodiversity. In this part of the world, the destruction of natural habitats for agriculture and urbanization is recurrent and very rapid while the current trend does not suggest a slowdown in the coming years [2]. Together with climate change, this loss in natural habitats and the intensification of agricultural practices are associated with major declines in biodiversity, especially in a decrease in insect biomass and diversity [2-4]. As reported by the Global Assessment on Biodiversity and Ecosystem Services, the preservation of biodiversity and human wellbeing are intertwined and there is a need to better understand all the services that can be provided by biodiversity [5]. Insects represent most of the known biodiversity on Earth and provide both services and disservices to human populations across the world [6]. Although most of the research on insects has focused on their negative impacts (e.g., as pests and vectors of human and livestock diseases and enemies of crops and vegetation), their beneficial effects on numerous key ecological functions, and therefore sustainable development goals, including those associated with the sustainable production of food, have become widely recognized [6-8]. Here, we review some of the most recent progress that has been made on understanding the positive impact of insects on sustainable food production for humans. Because the importance of insects as pollinators [8] producers of honey and regulators of pests (often other insects) [9] has been largely studied for years,

this article focuses on two research topics that have emerged in recent years: entomophagy, or the consumption of insects as food for humans and feed for other animals, and the beneficial impact of bioturbation by insects on soil and water dynamics and the maintenance of biodiversity.

Entomophagy and the 'Thai' example

Although entomophagy is likely to be as old as humanity, this practice has been relatively poorly studied until the last three years and has been very prolific in terms of scientific publications (116 and 117 articles referenced in Web of Science in 2020 and 2021, respectively, against ~50 articles year^{-1} between 2015 and 2017 and less than 20 year^{-1} before this period, keyword = 'entomophagy') [10]. Interestingly, this recent societal and scientific interest mainly originates in Western countries (~60% of the publications included scientists from Western countries, while entomology remains anecdotic in these countries; see below). Insects are currently considered a piece of the puzzle for reaching some sustainable development goals [11,12]. Edible insects are interesting as 'food', especially because they are particularly rich in proteins and contain essential amino acids, fatty acids and vitamins, and their production is considered environmentally friendly in comparison with the production of other sources of animal proteins [13]. Insects offer an alternative to the production of livestock meat, which requires much more energy, water and space than insects [12,14,15]. Some edible insect species contain as much protein as beef, more iron than spinach, as much vitamin B_{12} as salmon, all nine amino acids, and they are high in calcium, omega 3 and fiber contents [16]. They are therefore a means to prevent global undernutrition and food insecurity in low-income countries [17-19]. Since edible insects can also be used to feed poultry and fish in small villages, they contribute to local food security and rural development, in particular economically empowering women and supporting the livelihood of disadvantaged groups [20]. Insects are highly appreciated as edible food in many parts of the world, with at least 2 billion people occasionally eating insects, especially in South America, South and Southeast Asia and Sud-Saharan African countries [14]. Conversely, if the Western world is increasingly interested in insects for alternative sources of proteins and the positive impact of insect farming on numerous sustainable development goals [12], then this practice remains more of a possibility than a short-term solution in most Western countries. In fact, despite being considered as an emerging sector and growing business [11,16], the consumption of insects must face the challenge of reluctant Western customers, and its business model needs to be improved to become more competitive [14,21-23]. Moreover, although the exact number of consumed species is difficult to estimate, approximately 2100 species of insects are considered edible [24]. This number must be compared with the few species that are considered to be commercially interesting and farmed. For instance, in Europe, only seven species can be farmed for feeding animals (i.e., black soldier fly, common housefly, yellow mealworm, lesser mealworm, house cricket, banded cricket and field cricket) [25]. This clearly shows that most of the insects that are consumed in the world are harvested in the wild (92%) or on small local farms (semidomestication, 6%) [12]. Specific harvesting and preparing techniques have, therefore, been locally developed and, are part of the culture and patrimony of many low-income communities [26]. These geographical characteristics are even reinforced by the high seasonality associated with insect harvesting (e.g., termites are mostly consumed during their swarming, which limits their harvesting to a few days a year). This scenario obviously increases the interdependence between local communities and the preservation of their environment since the degradation of insect habitats leads to the loss of these nature-based resources, a dependence on expensive and imported food, and as a consequence food insecurity, poverty, and malnutrition [26]. This large difference between the number of farmed insects and the total number of edible insects also shows broad efforts in terms of economic and technological validation with the creation of insect farms from a circular economy perspective [12,27], which could locally improve human wellbeing without negatively impacting environmental resources [28]. An interesting example is the development of over 20,000 small-scale family insect farms in Thailand. In this country, people moved from harvesting insects from the wild (from forests and paddy fields) to rearing them on household farms. Guiné [15] reported an insect production (mainly crickets) of 7,500tons by over 20,000 listed household farms in Thailand, generating more than a million USD. This 'Thai' example [12] is considered a success story because it shows that local knowledge and practices can generate income, create employment and increase the livelihood of impoverished families if they receive support from academia research and private sectors.

Bioturbation by Insects and the 'Zai' Example

Insects can also impact the sustainable production of food indirectly through their impact on soil chemical, physical and biological quality. Although insects are mainly considered in terms of their negative effects as pests and herbivores, a significant number of articles show that some taxa can play a significant role in cycling nutrients and maintaining soil fertility [29,30]. Many insect species also spend part of their life cycle hidden in soil, for example during their underground larval stages (e.g., cicadas and many coleopteran species) or nesting in soil stages (e.g., some wasp and bee species and many termite and ant species). Their burrowing activities impact soil dynamics, with effects on soil structure and the dynamics of water, nutrients and biodiversity [31-33], although their effects are considered negligible in comparison with the action of earthworms [34] and termites [35]. If earthworms are currently the banner of sustainable agriculture, because of their positive effects on soil porosity and nutrient cycling, then most of the literature has focused on the negative impacts of termites as pests for plantations and crops [35,36]. However, the trend is perhaps reversed with the publication of several recent articles highlighting the positive impacts of termites and insects in general on ecosystem services [35,37-40]. Recent articles also showed the possibility of termites to favourably impacting not only soil porosity, water infiltration and the resistance of soil to erosion but also chemical elements that are

important for improving the resistance of plants to environmental stresses such as silicon [35,41]. Here again, local knowledge and practices have been locally proposed for increasing the sustainable production of agrosystems. The most interesting example is the Zai system practiced in sub-Sahelian ecosystems, and it consists of stimulating termite activity in the field to increase soil fertility and water infiltration and thereby plant growth and yield [35,42]. This traditional practice increases the productivity of the system from 0.5 to 5.3tons ha^{-1} for straw and from 0.15 to 1.7tons ha^{-1} for sorghum [43]. At a larger scale, termites can also create large islands of fertility and biodiversity hotspots at landscape scales. In the lower Mekong basin, in Laos, northeastern Thailand and Cambodia, these mounds can be used directly as amendments for increasing soil fertility (because of their higher soil organic matter and nutrient contents and amount of available Si, Muon R, Lai C, Hervé V, Zaiss R, Chassagne F, Bureau-Point E, Marchant S, Audibert M, Berger J, Wieringa F, Savouré A, Sok K, Meunier, J-D., Ann V, Jouquet, P, 2023. Abundance, perceptions and utilizations of termite mounds in Cambodia. Soil Use and Management, 00, 1–13. https://doi.org/10.1111/sum.12893), or they can be used to harvest plants, arthropods and other small mammals that shelter on or in them. This last use of termite mounds contributes to reducing food insecurity and provides improved access to health [35]. If most of the work on the impact of insects on the ecological functioning of soil has focused on natural or non-arable ecosystems, then these two examples provide interesting perspectives for the sustainable management of agro-ecosystems. They also highlight the need for a better understanding of the diversity of local knowledge and practices associated with the utilization of insects and, more generally, soil biodiversity to improve the fertility of soil and the sustainable production of food.

Perspectives

The link between the sustainable production of food and the preservation of biodiversity is not only biological but also cultural. Considerable advances have been achieved in recognizing the importance of local or traditional knowledge. The utilization of natural resources by local communities or ethnic groups can be very vast and should be seen as a source of inspiration for scientists [44]. Here, we used two examples to show that local knowledge and customs can sometimes be sources of inspiration for the development of innovative, environmentally friendly and effective practices: the Thai and Zai examples. Unfortunately, the degradation of natural resources and the shift to 'westernization' constitute major threats to the preservation of this traditional knowledge and, in parallel, to all the energy spent to find new technological sources of food and agricultural practices. This review advocates for consideration the diversity of solutions and adaptations that have been found in nature by local populations.

Acknowledgements

The authors would like to thank the CoSav SyAD initiative (Communautés de Savoirs Systèmes Alimentaires Durables) from IRD for having initiated this discussion and the writing of this review.

Author Contribution

Pascal Jouquet: Conceptualization, Writing; Ratha Muon, Saran Traoré, Ajay Harit: Reviewing and editing.

References

1. Daily GC, Ruckelshaus M (2022) 25 years of valuing ecosystems in decisions. Nature 606: 465-466.
2. Raven PH, Wagner DL (2021) Agricultural intensification and climate change are rapidly decreasing insect biodiversity. Proc Natl Acad Sci 118(2): e2002548117.
3. Outhwaite CL, Mc Cann P, Newbold T (2022) Agriculture and climate change are reshaping insect biodiversity worldwide. Nature 605: 97-102.
4. Pervez M, Manzoor F (2022) Honey bee losses and pesticides threat: An Asian perspective. Journal of Apicultural Research 62(1): 64-75.
5. Piccolo JJ, Taylor B, Washington H, Kopnina H, Gray J, et al. (2022) Nature's contributions to people and people moral obligations to nature. Biological Conservation 270: 109572.
6. Duffus NE, Christie CR, Morimoto J (2021) Insect cultural services: How insects have changed our lives and how can we do better for them. Insects 12: 377.
7. Dangles O, Casas J (2019) Ecosystem services provided by insects for achieving sustainable development goals. Ecosyst serv 35: 109-115.
8. Patel V, Pauli N, Biggs B, Barbour L, Boruff B (2021) Why bees are critical for achieving sustainable development. Ambio 50: 49-59.
9. Arnold SEJ, Elisante F, Mkenda PA, Tembo YLB, Ndakidemi PA, et al. (2021) Beneficial insects are associated with botanically rich margins with trees on small farms. Sci Rep 11: 15190.
10. Kavle RR, Pritchard ETM, Bekhit AEDA, Carne A, Agyei D (2022) Edible insects: A bibliometric analysis and current trends of published studies (1953-2021). International Journal of Tropical Insect Science 42: 3335-3355.
11. Madau FA, Arru B, Furesi R, Pulina P (2020) Insect farming for feed and food production from a circular business model perspective. Sustainability 12(13): 5418.
12. Moruzzo R, Mancini S, Guidi A (2021) Edible insects and sustainable development goals. Insects 12(6): 557.
13. Naseem R, Majeed W, Rana N, Koch EBA, Naseem MR (2021) Entomophagy: An innovative nutritional and economic navigational tool in race of food security. Int J of Trop Insect Sc 41: 2211-2221.
14. Lange K, Nakamura Y (2021) Edible insects as a source of food bioactives and their potential health effects. Journal of Food Bioactives 14: 4-9.
15. Guiné RPF, Correia P, Coelho C, Costa CA (2021) The role of edible insects to mitigate challenges for sustainability. Open Agriculture 6: 24-36.
16. Ordoñez RA, Egas EM (2021) Edible insects: A food alternative for the sustainable development of the planet. International Journal of Gastronomy and Food Science 23: 100304.
17. Chaalala S, Leplat A, Makkar H (2018) Importance of insects for use as animal feed in low-income countries. pp: 303-319.
18. Smith MR, Stull VJ, Patz JA, Myers SS (2021) Nutritional and environmental benefits of increasing insect consumption in Africa and Asia. Environ Res Lett 16(6): 065001.
19. A Van Huis (2021) Prospects of insects as food and feed. Organic Agriculture 11: 301-308.
20. Jochen D, Christian R (2021) Nature's "Free Lunch": The contribution of edible insects to food and nutrition security in the Central Highlands of Madagascar. Foods 10(12):2978.

21. Naranjo NG, Fanter M, Conconi AM, Floto SS (2021) Consumer acceptance among Dutch and German students of insects in feed and food. Food science & nutrition 9(1): 414-428.

22. A Van Huis (2022) Edible insects: Challenges and prospects. Entomological Research 52(4): 161-177.

23. Mancini S, Sogari G, Espinosa SD, Menozzi D, Paci G, et al. (2022) Exploring the future of edible Insects in Europe. Foods 11(3): 455.

24. Nakajima Y, Ogura A (2022) Genomics and effective trait candidates of edible insects. Food Bioscience 48: 101793.

25. Commission Regulation (EU) (2022) Official Journal of the European Union, 188.

26. Meysing A, Forneck S, Razafindrakotomamonjy A, Dürr J (2022) Why socio-economic and attitudinal factors cannot predict entomophagy in rural areas of Madagascar. Journal of Insects as Food and Feed 8(5): 579-592.

27. Adams F, Aidoo R, Mensah JO, Mensah A, Amankwah K, et al. (2021) Commercialisation of African palm weevil larvae for employment creation and nutritional security in rural Ghana: A financial feasibility approach. J Insect Food Feed 7(6): 1-10.

28. Lumanlan JC, Williams M, Jayasena V (2022) Edible insects: Environmentally friendly sustainable future food source. International Journal of Food Science & Technology 57(10): 6317-6325.

29. Barragán F, Douterlungne D, Ramírez AH, Gelviz SMG, Miranda AVG, et al. (2022) The rolling dung master: An ecosystem engineer beetle mobilizing soil nutrients to enhance plant growth across a grassland management intensity gradient in drylands. Journal of Arid Environments 197: 104673.

30. Hidalgo FJ, Canepuccia AD, Arcusa J, Fanjul E, Álvarez G, et al. (2021) Black fire ant mounds modify soil properties and enhanced plant growth in a salt marsh in Argentina. Estuar Coast Shelf S 261: 107534.

31. Bétard F (2021) Insects as zoogeomorphic agents: an extended review. Earth Surf Proc Land 46(1): 89-109.

32. Cheik S, Jouquet P, Maeght JL, Capowiez Y, Tran TM, et al. (2021) X-ray tomography analysis of soil biopores structure under wetting and drying cycles. European J Soil Sci 72(5): 2128-2132.

33. Groom KM (2022) It's an insects world, we just live on it: Exploring entomogeomorphology as a potential subdiscipline of Geography. Physical Geography 43: 52-66.

34. Vogel HJ, Balseiro MR, Kravchenko A, Otten W, Pot V, et al. (2021) A holistic perspective on soil architecture is needed as a key to soil functions. Eur J Soil Sci 73(1): e13152.

35. Jouquet P, Traoré S, Harit A, Choosai C, Cheik S, et al. (2020) Moving beyond the distinction between the bright and dark sides of termites to achieve sustainable development goals. Curr Opin Insect Sci 40: 71-76.

36. Faith Oi (2022) A review of the evolution of termite control: A continuum of alternatives to termiticides in the united states with emphasis on efficacy testing requirements for product registration. Insects 13(1): 50.

37. Duran EHB, Armbrecht I, Acioli ANS, Suárez JC, Romero M, et al. (2020) Termites as indicators of soil ecosystem services in transformed amazon landscapes. Ecological Indicators 117: 106550.

38. Elizalde L, Arbetman M, Arnan X, Eggleton P, Leal IR, et al. (2020) The ecosystem services provided by social insects: traits, management tools and knowledge gaps. Biol Rev 95(5): 1418-1441.

39. Oluleye A, Ogunwole J, Adeyemo A, Shittu O, Osakwe U, et al. (2021) Soil fertility status of termite mounds for the promotion of ecosystem services in agro-ecosystems. Environmental Sciences and Ecology: Current Research 2(1): 1011.

40. Wijas B, Atkinson J (2021) Termites in restoration-the forgotten insect? Restor Ecol 29(8): e13511.

41. Souri Z, Khanna K, Karimi N, Ahmad P (2021) Silicon and plants: current knowledge and future prospects. J Plant Growth Regul 40: 906-925.

42. Beteo Z, Omer SC, Souleymane O, Patrice T, Thomas D (2022) Diffusion of water harvesting for rainfed agriculture in sub-Saharan Africa: Case of zaï practice in Burkina Faso. Journal of Development and Agricultural Economics 14: 50-59.

43. Jouquet P, Chaudhary E, Kumar ARV (2018) Sustainable use of termite activity in agro-ecosystems with reference to earthworms. A review. Agron Sustain Dev 38: 3.

44. Cheik S, Jouquet P (2020) Integrating local knowledge into soil science to improve soil fertility. Soil Use Management 36(4): 561-564.