Article

Eco-Sustainability assessment of Integrated Pest Management (IPM): Indicator system and calculator

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Abstract
Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on sustainable control of pests through a combination of techniques. In present study, an indicator system, which is a hierarchical system, for eco-sustainability assessment of Integrated Pest Management is proposed. The indicator system is based on various IPM techniques in which an indicator represents a category of IPM techniques (external interventions). The eco-sustainability assessment follows such criteria as the impact of external interventions on the ecosystem and environment (e.g., ecosystem completeness, environmental impact, and human health impact, etc.), the intensity and frequency of external interventions, and the sustainability of IPM. In the assessment system, all categories of IPM techniques are scored and the weighted score for IPM techniques used is calculated for the assessment of IPM sustainability. A calculator is developed for assessment. The calculator is web browser based that includes both online and offline versions and can be used on web browsers. The system can be used to assess an IPM programme and compare between IPM programmes, or used as a tool for IPM teaching and training.

Keywords Integrated Pest Management (IPM); techniques; ecosystem; sustainability; assessment; ecological impact; calculator.

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1 Introduction

Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on sustainable control of pests through a combination of techniques (Peshin et al., 2009; Zhang, 2018). In plant protection practices, IPM, although advocated for decades, still determines the use of pesticides (Peshin and Zhang, 2014). IPM has limited acceptance because it is economically feasible and tolerates the use of pesticides compared to simple chemical control (Peshin et al., 2023). However, IPM requires knowledge-intensive management, which is complex and is relatively difficult to popularize and sustain (Way and Heong, 1994; Matson et al., 1997). The biodiversity in traditional agricultural ecosystems can be compared with natural systems. These systems have the advantages of stable production, minimized risks, less pests and diseases, less resource use, and a high output-input ratio. Improving the functional diversity of farmland ecosystems is a key strategy for sustainable production (Altieri, 1999; Zhang et al., 2014). The more diverse the farmland ecosystem, the better the stability of the insect community. For example, a rice farmer in Laguna Province, Philippines, planted 24ha of rice and had not applied drip pesticides for 15 years. However, the yield in the rainy and dry seasons was 10.81% and 60.98% higher than that in the pesticide fields. The surrounding 550 rice farmers saw the results and stopped using pesticides (IRRI, 1997-1998). According to research (Altieri, 1994, 1995; Altieri and Letourmeau, 1984), in the crop-weed-insect system, weeds affect the diversity of insects (plant eaters, natural enemies), and adjacent vegetation provides food for natural enemies (Boatman, 1994), so there are fewer pests in the fields with more crops. Therefore, it is necessary to maintain a certain number of harmless weeds (IRRI 1997-1998), vegetation strips along the edge of the field, and a certain number of perennial plots (such as orchards, where the vegetation is stable, less disturbed, structurally stable, and with more natural enemies) (Altieri, 1999; Zhang et al., 2014). Greiler and Tschamtke (1993) found that in a comparison of cultivated land, fallow land, and grassland, if the degree of cultivated land intensiveness is high, the number of insects is large, but the diversity is low. Szentriralyi and Kozar (1991) observed Hungarian apple orchards and found that low management intensity and high diversity of surrounding vegetation led to high species diversity, and about 50% of the collected species came from the surrounding habitats. A five-year observation of Hungarian apple orchards found that there were 1759 arthropod species, and chemical treatment had the greatest impact on diversity, followed by plant diversity in orchards and surrounding areas. Kleiman et al. (2021) compared mango trees on local farms in Florida. One field had trees surrounded by hundreds of different species of flowering weeds. The other field was maintained without weeds. It was found that pollinators preferred the trees surrounded by weeds. In turn, the trees benefited and produced more mangoes. Iamba and Teksep (2021) conducted an experiment to attract natural enemies with marigold (*Tagetes erecta* L.) in upland rice fields. The principle is to use marigold to modify the habitat of upland rice to provide important resources needed by natural enemies to suppress pest populations. Among the four treatments used, the plots with marigold as shelter plants attracted the largest number of natural enemies (*Apanteles* sp., *Telenomus* sp., *Oxypes javanus*, *Coelophora inaequalis*) populations. Four ecological hypotheses have been proposed to explain how insect populations in farmland ecosystems can be stabilized by building vegetation structures that support natural enemies or inhibit pest damage (Altieri, 1994). A large number of studies have shown that biodiversity in farmland or the surrounding environment of farmland has a natural check and balance effect on pests, which can be used to reduce the application of chemical pesticides, enhance the ability of farmland to resist natural disasters, and is beneficial to crop production (Andow, 1991; Way and Heong, 1994). Pesticides cost the world tens of billions of dollars each year, but natural enemies in ecosystems provide 5-10 times the control power of pesticides. The consequences of losing natural control will be very serious (Pimental et al., 1992). By utilizing the natural equilibrium mechanism of the agricultural ecosystem, we can minimize the impact on the ecosystems and the environment while naturally controlling pests, thus ensuring the sustainability of IPM.

To better promote IPM sustainability, an indicator system for eco-sustainability assessment of Integrated Pest Management is proposed in present study. The indicator system is based on various IPM techniques in which an indicator represents a category of IPM techniques (external interventions). The eco-sustainability assessment follows criteria the impact of external interventions on the ecosystem and environment, the intensity and frequency of external interventions, and IPM sustainability. The system is expected to be used for assessing an IPM programme and comparing between IPM programmes, or used as a tool for IPM teaching and training.

2 Indicator System

2.1 Framework of Indicator System

Based on the earlier work (Zhang, 2018b), here I proposes the framework of indicator system for eco-sustainability assessment of Integrated Pest Management (IPM) (Greiler and Tscharntke, 1993; Matson et al., 1997; Tilman, 1999; Peshin et al., 2009; Li et al., 2014; Peshin and Zhang, 2014; Peshin et al., 2023). The indicator system is based on various IPM techniques, in which an indicator represents a category of IPM techniques (external interventions). The eco-sustainability assessment follows these criteria: (1) the impact of external interventions on the ecosystem and environment (Carson, 1962; Abdolmaleki et al., 2023): (a) ecosystem completeness (Willcox et al., 2023); (b) environmental impact, (c) human health impact (Chen et al., 2004; Chen et al., 2005; Zhang et al., 2018); (2) the intensity and frequency of external interventions, and (3) the sustainability of IPM, i.e., the long-term availability, applicability and acceptability of IPM. The framework (Fig. 1), which is a hierarchical system (Zhang, 2019; Tlas, 2025), is as follows:

IPM-NE - Natural equilibrium: native ecosystem and native biodiversity, no or little human intervention (Shepard et al., 1987; Andow, 1991; IRRI 1997-1998; Pimentel, 1997; Pimental et al., 1992; Way and Heong, 1994; Altieri, 1994, 1995, 1999; Altieri and Letourneau, 1984; Cardinale et al., 2006; Zhang, 2007; Nedorezov and Neklyudova, 2014; Zhang et al., 2014; Ranjith et al., 2019; Rana, 2020; Kleiman et al., 2021; Ankit et al., 2024; Tiwari et al., 2024).

IPM-NE-NE - Natural ecosystem. Native ecosystem; pests are completely controlled by natural equilibrium such as native biodiversity and native food web, and no human intervention at all (Hawkins and Lawton, 1987; Szentkirályi et al., 1991; Barrion and Litsinger, 1995; Schoenly et al., 1998; Firbank et al., 2005; Hooper et al., 2005; Zhang, 2011, 2016, 2018a).

IPM-NE-AE - Artificially assisted natural ecosystem (Boatman, 1994; Iamba and Teksep, 2021; Walston et al., 2024). For native ecosystems with defective natural equilibrium mechanisms, complete natural equilibrium is achieved by permanently changing the living environment of pests. For example, using natural pest-resistant plants or that bred by traditional methods, creating shelters for natural enemies, improving irrigation facilities, etc.

IPM-PA - Physical and agricultural control: use physical or agricultural control techniques (Peshin et al., 2009; Mickael et al., 2015).

IPM-PA-PH - Physical control: use light traps, sound traps, sex hormone traps, magnetic control, etc.

IPM-PA-AG - Agricultural control: use intercropping, crop rotation, manual pest removal, weed removal, soil plowing for pest control, drainage/irrigation for pest control, etc.

IPM-BC - Biological control: introduce natural enemies or use targeted molecules in the ecosystem (Croft, 1990; Guo et al., 2007; Peshin et al., 2009).

IPM-BC-AN - Release native animal natural enemies (Crawley, 1992; Jiang et al., 2015; Jiang and Zhang, 2015). By releasing more native animal natural enemies in the ecosystem, the existing population size of native animal natural enemies (e.g., beneficial arthropods, etc.) is increased.

IPM-BC-LM - Use native pathogenic microorganisms to directly control pests. Spray pathogenic microorganisms to infect and kill pests, which may cause significant epidemics (e.g., pathogenic fungi, viruses, bacteria, etc.) (Zhang et al., 1996; Zhang et al., 1997; Schoenly et al., 2003; Sanjaya et al., 2013).

IPM-BC-EN - Release exogenous natural enemies (e.g., animals, pathogenic microorganisms, etc.) to control pests, or use targeted molecules to control pests.

IPM-GM - Introduce genetically modified organisms into the ecosystem (Zhang and Pang, 2009).

IPM-GM-NP - Introduce genetically modified natural enemies (e.g., animals, pathogenic microorganisms, etc.)

or pests into the ecosystem.
IPM-GM-PL - Use genetically modified pest-resistant plants in the ecosystem.
IPM-CC - Chemical control: Use natural or synthetic pesticide chemicals in the ecosystem (Pimentel, 2009a-b; Liu et al., 2002; Guo et al., 2007; Peshin et al., 2007; Cai, 2008; Kumar et al., 2013; Darvishzadeh et al., 2014; Jafarbeigi et al., 2014; Peshin and Zhang, 2014; Mardani et al., 2017).
IPM-CC-NC - Control pests with natural chemicals (Jafarbeigi et al., 2014; Sharifian et al., 2015; Gupta et al., 2017). Use natural chemicals extracted from plants or other organisms to control pests, or use other natural products, such as minerals, to control pests.
IPM-CC-CC - Control pests with synthetic chemicals. Use synthetic chemicals, such as organophosphorus pesticides, to control pests.
IPM-CC-SL - Use low toxic, or other low-risk synthetic chemicals (Zhang and Liu, 2023).
IPM-CC-BH - Use highly toxic, or other high-risk synthetic chemicals.

From IPM-NE to IPM-CC, the negative ecological and environmental impact of external interventions increases, the intensity and frequency of external interventions increase, and the IPM sustainability decreases.

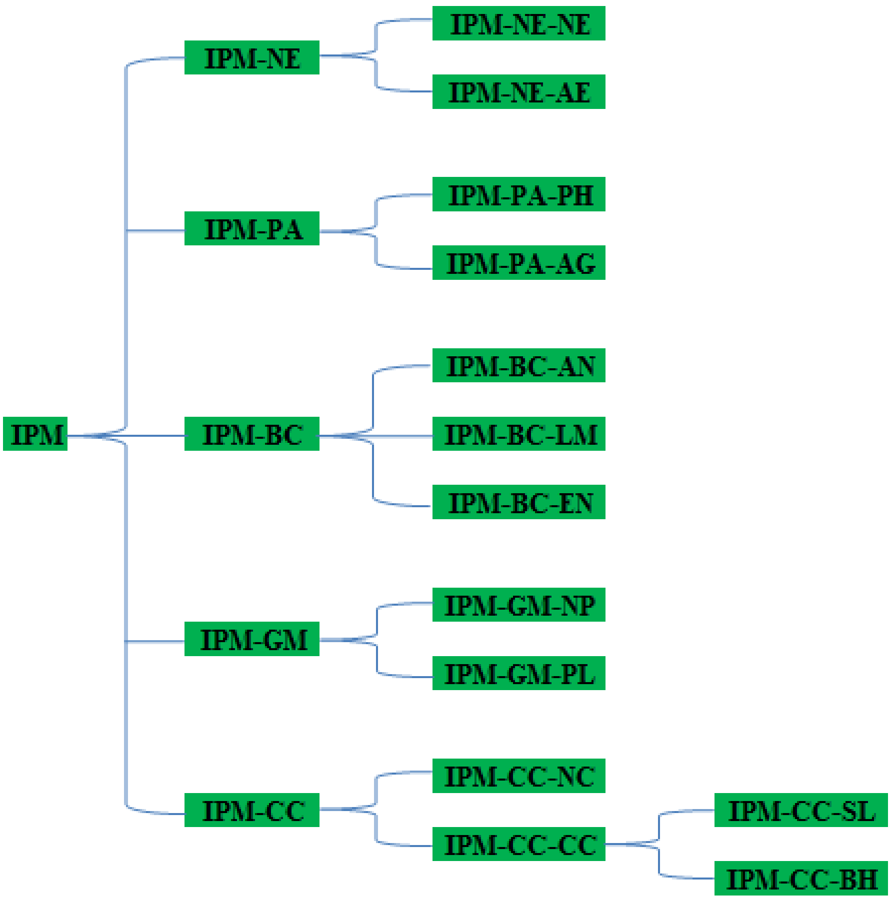

Fig. 1 Framework of indicator system for eco-sustainability assessment of Integrated Pest Management (IPM).

2.2 Indicator scoring

Indicator scoring depends on the different economic and social conditions of various countries and regions. Here I assign a set of scores for indicators, as listed bellow:

IPM-NE(1.0): IPM-NE-NE(1.0), IPM-NE-AE(0.5)
IPM-PA(0.7): IPM-PA-PH(1.0), IPM-PA-AG(0.5)
IPM-BC(0.5): IPM-BC-AN(1.0), IPM-BC-LM(0.8), IPM-BC-EN(0.5)
IPM-GM(0.3): IPM-GM-NP(1.0), IPM-GM-PL(0.5)
IPM-CC(0.1): IPM-CC-NC(1.0), IPM-CC-CC(0.5), IPM-CC-SL(1.0), IPM-CC-BH(0.0)

2.3 Assessment method

I use score-averaging to calculate IPM score for eco-sustainability of Integrated Pest Management (IPM). In this method, the maximum score is 1 and the minimum score is near 0. The closer it is to 1, the better the IPM sustainability is, and the closer it is to 0, the worse the IPM sustainability is.

For example, in the 1st IPM programme, two techniques are used: IPM-NE-AE, IPM-PA-PH. The IPM score will be:

IPM score={[IPM-NE×(1+IPM-NE-AE)+IPM-PA×(1+IPM-PA-PH)]/2}/2=0.73

For the 2nd IPM programme, four techniques are used: IPM-NE-AE, IPM-PA-AG, IPM-BC-LM, and IPM-CC-SL. The IPM score will be:

IPM score={[IPM-NE×(1+IPM-NE-AE)+IPM-PA×(1+IPM-PA-AG)+IPM-BC×(1+IPM-BC-LM)+IPM-CC×(1+IPM-CC-CC×(1+IPM-CC-SL))]/2}/4=0.46

For the 3rd IPM programme, three techniques are used: IPM-BC-EN, IPM-CC-NC, IPM-CC-BH. The IPM score will be:

IPM score={[IPM-BC×(1+IPM-BC-EN)+IPM-CC×(1+IPM-CC-NC)+IPM-CC×(1+IPM-CC-CC×(1+IPM-CC-BH))]/2}/3=0.18

Obviously, IPM sustainability of the 1st IPM programme is the best, seconded by the 2nd programme, and the 3rd IPM programme is the worst. The IPM sustainability of the 1st IPM programme is high (→1.0), the 2nd programme is approximately intermediate, and the 3rd programme is low (→0.0).

3 Calculator

Based on the previous description, I developed the calculator, IPM-AssessCal, for eco-sustainability assessment of Integrated Pest Management (IPM) using Javascript (Zhang, 2024a-b; Zhang and Qi, 2024, 2025). It includes both online (http://www.iaees.org/publications/journals/ces/articles/2025-15(3)/IPM-AssessCal.htm) and offline versions, and can be used for various computing devices (PCs, iPads, smartphones, etc.), operating systems (Windows, Mac, Android, Harmony, etc.) and web browsers (Chrome, Firefox, Sougo, 360, etc)(Fig. 2).

Offline tool can be found at:
http://www.iaees.org/publications/journals/ces/articles/2025-15(3)/e-suppl/IPM-AssessCal.rar
Double-click the offline tool, it will be opened in the default web browser.

The following are full Javascript codes of the calculator, IPM-AssessCal:

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<br>Also, click <a href="http://www.iaees.org/publications/journals/ces/articles/2025-15(3)/2-Zhang-Abstract.asp"><b>here</b></a> to download the corresponding offline calculator.
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    <input type="checkbox" name="ipmnenes" onClick="runipm()"> IPM-NE-NE <input type="text" name="IPMNENE" value="1.0" style="background:cyan;color:maroon" size=1>: Natural ecosystem. Native ecosystem; pests are completely controlled by natural equilibrium such as native biodiversity and native food web, and no human intervention at all. <br>
    <input type="checkbox" name="ipmneaes" onClick="runipm()"> IPM-NE-AE <input type="text" name="IPMNEAE" value="0.5" style="background:cyan;color:maroon" size=1>: Artificially assisted natural ecosystem. For native ecosystems with defective natural equilibrium mechanisms, complete natural equilibrium is achieved by permanently changing the living environment of pests. For example, using natural pest-resistant plants or that bred by traditional methods, creating shelters for natural enemies, improving irrigation facilities, etc. <br>
IPM-PA <input type="text" name="IPMPA" value="0.7" style="background:cyan;color:maroon" size=1>: Physical and agricultural control: use physical or agricultural control techniques. <br>
    <input type="checkbox" name="ipmpaphs" onClick="runipm()"> IPM-PA-PH <input type="text" name="IPMPAPH" value="1.0" style="background:cyan;color:maroon" size=1>: Physical control: use light traps, sound traps, sex hormone traps, magnetic control, etc. <br>
    <input type="checkbox" name="ipmpaags" onClick="runipm()"> IPM-PA-AG <input type="text" name="IPMPAAG" value="0.5" style="background:cyan;color:maroon" size=1>: Agricultural control: use intercropping, crop rotation, manual pest removal, weed removal, soil plowing for pest control, drainage/irrigation for pest control, etc. <br>
IPM-BC <input type="text" name="IPMBC" value="0.5" style="background:cyan;color:maroon" size=1>: Biological control:
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introduce natural enemies or use targeted molecules in the ecosystem.

    <input type="checkbox" name="ipmbcans" onClick="runipm()"> IPM-BC-AN <input type="text" name="IPMBCAN" value="1.0" style="background:cyan;color:maroon" size=1>: Release native animal natural enemies. By releasing more native animal natural enemies in the ecosystem, the existing population size of native animal natural enemies (e.g., beneficial arthropods, etc.) is increased.

    <input type="checkbox" name="ipmbclms" onClick="runipm()"> IPM-BC-LM <input type="text" name="IPMBCLM" value="0.8" style="background:cyan;color:maroon" size=1>: Use native pathogenic microorganisms to directly control pests. Spray pathogenic microorganisms to infect and kill pests, which may cause significant epidemics (e.g., pathogenic fungi, viruses, bacteria, etc.).

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    <input type="checkbox" name="ipmgmnps" onClick="runipm()"> IPM-GM-NP <input type="text" name="IPMGMNP" value="1.0" style="background:cyan;color:maroon" size=1>: Introduce genetically modified natural enemies (e.g., animals, pathogenic microorganisms, etc.) or pests into the ecosystem.

    <input type="checkbox" name="ipmgmpls" onClick="runipm()"> IPM-GM-PL <input type="text" name="IPMGMPL" value="0.5" style="background:cyan;color:maroon" size=1>: Use genetically modified pest-resistant plants in the ecosystem.

IPM-CC <input type="text" name="IPMCC" value="0.1" style="background:cyan;color:maroon" size=1>: Chemical control: Use natural or synthetic pesticide chemicals in the ecosystem.

    <input type="checkbox" name="ipmccncs" onClick="runipm()">IPM-CC-NC <input type="text" name="IPMCCNC" value="1.0" style="background:cyan;color:maroon" size=1>: Control pests with natural chemicals. Use natural chemicals extracted from plants or other organisms to control pests, or use other natural products, such as minerals, to control pests.

    IPM-CC-CC <input type="text" name="IPMCCCC" value="0.5" style="background:cyan;color:maroon" size=1>: Control pests with synthetic chemicals. Use synthetic chemicals, such as organophosphorus pesticides, to control pests.

        <input type="checkbox" name="ipmccsls" onClick="runipm()"> IPM-CC-SL <input type="text" name="IPMCCSL" value="1.0" style="background:cyan;color:maroon" size=1>: Use low toxic, or other low-risk synthetic chemicals.

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IPM score for sustainability (0,1]:

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User manual guide:

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4 Discussion

The present study focuses on the eco-sustainability assessment of qualitative combination of IPM techniques. Actually, the eco-sustainability assessment of IPM is a complex quatitative process. For example, for the same chemical control, the intensity and frequency of pesticide uses may be different, which may lead to distinctive eco-sustainability. Further studies on quantitative assessment are needed in the future.

The definition of “Intermediate” in eco-sustainability assessment of an IPM programme, should be dependent upon local conditions and development levels. For example, the standard score for defining

“Intermediate” may be 0.5, 0.4, or 0.3, etc. In addition, the indicator-scoring in the assessment system is relative. Users can give scores as needed.

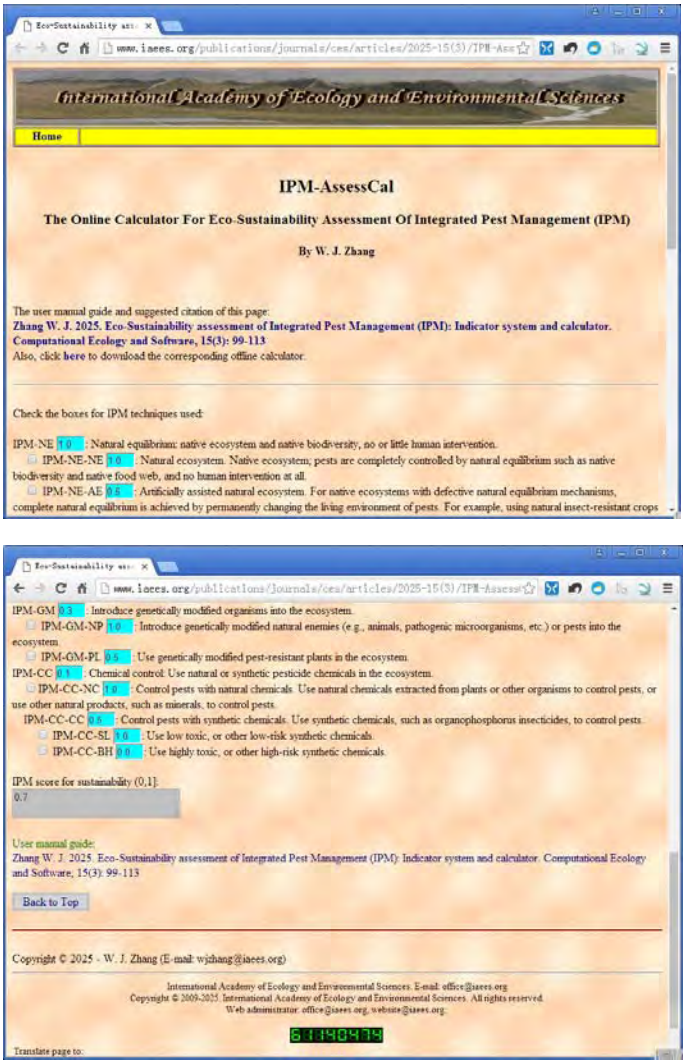

Fig. 2 Web page of IPM-AssessCal.

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References

Abdolmaleki SS, Sahragard A, Damavandian MR, et al. 2023. Effects of different pest managements on biodiversity of insects in citrus orchards of Babolsar and Hadishahr districts in Iran. Arthropods, 12(3): 156-170

Altieri MA. 1994. Biodiversity and Pest Management in Agroecosystems. Haworth Press, New York, USA

Altieri MA. 1995. Agroecology: the Science of Sustainable Agriculture. Westview Press, Boulder, CO, USA
Altieri MA. 1999. The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems and Environment, 74: 19-31
Altieri MA, Letourneau DK. 1984. Vegetation diversity and insect pest outbreaks. CRC Critical Reviews in Plant Sciences, 2: 131-169
Andow DA. 1991. Vegetational diversity and arthropod population response. Annual Review of Entomology, 36: 561-586
Ankit, Peshin R, Sharma R, et al. 2024. Varietal diversity of rice and wheat in Subtropical North India. Indian Journal of Ecology, 51(06): 1365-1371
Barrion AT, Litsinger JA. 1995. Riceland Spiders of South and Southeast Asia. CABI and IRRI.
Boatman N. 1994. Field Margins: Integrating Agriculture and Conservation. British Crop Protection Council, Surrey, England
Cai DW. 2008. Understand the role of chemical pesticides and prevent misuses of pesticides. Bulletin of Agricultural Science and Technology, 1: 36-38
Cardinale BJ, Srivastava DS, Duffy JE, Wright JP, Downing AL, Sankaran M, Jouseau C. 2006. Effects of biodiversity on the functioning of trophic groupsand ecosystems. Nature, 443: 989-992
Carson R. 1962. Silent Spring. Houghton Mifflin Company, Boston, USA
Chen JP, Lin G, Zhou BS. 2004. Correlation between pesticides exposure and mortality of breast cancer. China Public Health, 20: 289-290
Chen SY, Wang HF, Yi Y. 2005. The reporting system of acute pesticides poisoning and general situation of pesticides poisoning in China. Chinese Journal of Industrial Hygiene and Occupational Diseases, 5
Crawley MJ. 1992. Natural enemies: the population biology of predators, parasites and diseases. Blackwell Scientific Publications, Oxford, UK
Croft BA. 1990. Arthropod biological control agents and pesticides. Wiley Interscience, New York, USA
Darvishzadeh A, Salimian-Rizi S, Katoulinezhad AA. 2014. Effect of Biolep®, Permethrin and Hexaflumuron on mortality of cotton bollworm, *Helicoverpa armigera* (Noctuidae: Lepidoptera). Arthropods, 3(4): 161-165
Firbank LG. 2005. Striking a new balance between agricultural production and biodiversity. Annual Applied Biology, 146: 163-175
Greiler HJ, Tscharntke T. 1993. Zur Entomofauna von Getreideacker, Rotations- und Dauerbrache (Malaisefallen-Fänge). Mitteilungen der Deutschen Gesellschaft f r Allgemeine und Angewandte Entomologie, 8: 387-390
Guo XF, Zhang HF, Li JG. 2007. The importance of fungicides/bactericides in American agriculture. World Pesticides, 9(3): 21-25
Gupta S, Chauhan NS, Bhushan S, et al. 2017. Insecticidal, food utilisation and biochemical effect of essential oils extracted from seeds of *Brassica juncea* (Czern.) against *Spodoptera litura* (Lepidoptera: Noctuidae) (Fabricius). Arthropods, 6(3): 93-106
Hawkins BA, Lawton JH. 1987. Species richness for parasitoids of British phytophagous insects. Nature, 326:788-790
Hooper DU, Chapin FS, Ewel JJ, Hector A, Inchausti P, Lavorel S, Lawton JH, Lodge DM, Loreau M, Naeem S, Schmid B, Setala H, Symstad AJ, Vandermeer J, Wardle DA. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. Ecological Monographs, 75: 3-35
Iamba K, Teksep C. 2021. Biological role of marigold (*Tagetes erecta* L.) in habitat manipulation and sustenance of natural enemy populations in upland rice. Arthropods, 10(3): 66-81

IRRI 1997-1998: Biodiversity Maintaining the Balance. International Rice Research Institute, Philippines

Jafarbeigi F, Samih MA, Zarabi M, et al. 2014. Sublethal effects of some botanical and chemical insecticides on the cotton whitefly, *Bemisia tabaci* (Hem: Aleyrodidae). Arthropods, 3(3): 127-137

Jiang LQ, Zhang WJ. 2015. Effects of parasitism on robustness of food webs. Selforganizology, 2(2): 21-34. http://www.iaees.org/publications/journals/selforganizology/articles/2015-2(2)/effects-of-parasitism-on-robustness-of-food-webs.pdf

Jiang LQ, Zhang WJ, Li X. 2015. Some topological properties of arthropod food webs in paddy fields of South China. Network Biology, 5(3): 95-112. http://www.iaees.org/publications/journals/nb/articles/2015-5(3)/topological-properties-of-arthropod-food-webs-in-paddy-fields.pdf

Kleiman BM, Koptur S, Jayachandran K. 2021. Weeds enhance pollinator diversity and fruit yield in mango. Insects, 12(12): 1114

Kumar JIN, Bora A, Kumar RN, et al. 2013. Toxicity analysis of pesticides on cyanobacterial species by 16S rDNA molecular characterization. Proceedings of the International Academy of Ecology and Environmental Sciences, 3(2): 101-132

Mickael H, Christophe M, Thibaud D, Johanne N, Benjamin P, Jodie T, Yvan C. 2015. Orchard management influences both functional and taxonomic ground beetle (Coleoptera, Carabidae) diversity in South-East France. Applied Soil Ecology, 88: 26-31

Li N, Zhang WJ, Li X. 2014. A brief manual of technical specification for integrated control of major rice insect pests in China. Environmental Skeptics and Critics, 3(3): 61-64. http://www.iaees.org/publications/journals/environsc/articles/2014-3(3)/brief-manual-of-technical-specification-for-integrated-control.pdf

Liu CJ, Men WJ, Liu YJ, et al. 2002. The pollution of pesticides in soils and its bioremediation. System Sciemces and Comprehensive Studies in Agriculture, 18(4): 295-297

Mardani A, Almasi A, Hashemi SM, et al. 2017. Side effects of thiacloprid+deltamethrin, pirimicarb and pymetrozine on the black bean aphid parasitoid, *Lysiphlebus fabarum* Marshall (Hymenoptera: Aphidiidae). Arthropods, 6(2): 67-77

Matson PA, Parton WJ, Power AG, Swift MJ. 1997. Agricultural intensification and ecosystem properties. Science, 277: 504-509

Nedorezov LV, Neklyudova. 2014. Continuous-discrete model of parasite-host system dynamics: Trigger regime at simplest assumptions. Computational Ecology and Software, 4(3): 163-169

Peshin R, Bandral RS, Zhang WJ, et al. 2009. Integrated Pest Management: A Global Overview of History, Programs and Adoption. In: Integrated Pest Management: Innovation-Development Process (Vol. 1) (Peshin R, Dhawan AK, eds). 1-50, Springer, Netherlands

Peshin R, Kalra R, Dhawan AK, et al. 2007. Evaluation of insecticide resistance management based integrated pest management programme. AI and Society, 21: 357-381

Peshin R, Singh K, Garg L, et al., 2023. Impact evaluation of rice integrated pest management dissemination programs on adoption and pesticide use in Punjab, India. International Journal of Tropical Insect Science, 43: 869-880

Peshin R, Zhang WJ. 2014. Integrated Pest Management and Pesticide Use. In: Integrated Pest Management: Pesticide Problems (Vol. 3) (Pimentel D, Peshin R, eds). 1-46, Springer, Netherlands

Pimentel D. 1997. Techniques for Reducing Pesticide Use: Environmental and Economic Benefits. John Wiley and Sons, Chichester, USA

Pimentel D. 2009a. Pesticides and pest control. In: Integrated Pest Management: Innovation-Development

Process (Vol. 1) (Rajinder P, Dhawan A, eds). 83-87, Springer, Netherlands

Pimentel D. 2009b. Environmental and economic costs of the application of pesticides primarily in the United States. In: Integrated Pest Management: Innovation-Development Process (Vol. 1) (Rajinder R, Dhawan A, eds). 88-111, Springer, Netherlands

Pimental, D, Stachow, U, Takacs, DA, et al. 1992. Conserving biological diversity in agricultural/forestry systems. Bioscience, 42(5): 354-362

Rana S. 2020. Dynamic complexity in a discrete-time predator-prey system with Michaelis-Menten functional response: Gompertz growth of prey. Computational Ecology and Software, 10(3): 117-132

Ranjith KG, Kalyan D, Lakshminarayan K, Ravindra RB. 2019. Crowding effects and depletion mechanisms for population regulation in prey-predator intraspecific competition model. Computational Ecology and Software, 9(1): 19-36

Sanjaya Y, Ocampo VR, Caoili BL. 2013. Selection of entomopathogenic fungi against the red spider mite *Tetranychus kanzawai* (Kishida) (Tetranychidae: Acarina). Arthropods, 2(4): 208-215

Schoenly KG, Cohen MB, Barrion AT, Zhang WJ, Gaolach B, Viajante VD. 2003. Effects of *Bacillus thuringiensis* on non-target herbivore and natural enemy assemblages in tropical irrigated rice. Environmental Biosafety Research, 3: 181-206

Schoenly K, Justo H Jr, Barrion AT, Harris MK, Bottrell DG. 1998. Analysis of invertebrate biodiversity in a Philippine farmer’s irrigated rice field. Environmental Entomology, 27(5): 1125-1136

Sharifian I, Darvishzadeh A. 2015. Chemical composition and insecticidal efficacy of essential oil of *Echinophora platiloba* DC (Apiaceae) from Zagros foothills, Iran. Arthropods, 4(2): 38-45

Shepard BM, Barrion AT, Litsinger JA. 1987. Helpful Insects, Spiders, and Pathogens. International Rice Research Institurte, Los Banos, Philippines

Szentkirályi F, Kozár F. 1991. How many species are there in apple insect communities? Testing the resource diversity and intermediate disturbance hypotheses. Ecological Entomology, 16: 491-503

Tilman D. 1999. Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. Proceeding of National Academic Science of USA, 96: 5995-6000

Tiwari KM, Tripathi PN, Singh R. 2024. Biodiversity of aphidophagous predators in Ayodhya district, Uttar Pradesh, India. Arthropods, 13(3): 120-156

Tlas M. 2025. Using the analytic hierarchy process in an interactive interior point algorithm for mathematical multiple-objective nonlinear programming problems. Selforganizology, 12(1-2): 1-20

Walston LJ, Hartmann HM, Fox L. 2024. If you build it, will they come? Insect community responses to habitat establishment at solar energy facilities in Minnesota, USA. Environmental Research Letters, 19: 014053

Way MJ, Heong KL. 1994. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice-a review. Bulletin of Entomological Research, 84: 567-587

Willcox BK, Potts SG, Brown, MJF. et al. 2023. Emerging threats and opportunities to managed bee species in European agricultural systems: a horizon scan. Scientific Reports, 13(18099)

Zhang WJ. 2007. Computer inference of network of ecological interactions from sampling data. Environmental Monitoring and Assessment, 124: 253-261. https://link.springer.com/article/10.1007/s10661-006-9223-8

Zhang WJ. 2011. Constructing ecological interaction networks by correlation analysis: hints from community sampling. Network Biology, 1(2): 81-98. http://www.iaees.org/publications/journals/nb/articles/2011-1(2)/Constructing-ecological-interaction-networks-by-correlation-analysis.pdf

Zhang WJ, Wang R, Zhang DL, Wei W, Chen HD. 2014. Interspecific associations of weed species around rice fields in Pearl River Delta, China: A regional survey. Selforganizology, 1(3-4): 143-205. http://www.iaees.org/publications/journals/selforganizology/articles/2014-1(3-4)/interspecific-associations-of-weed-species.pdf

Zhang WJ. 2016. Selforganizology: The Science of Self-Organization. World Scientific, Singapore. http://www.worldscientific.com/worldscibooks/10.1142/9685

Zhang WJ. 2018a. Fundamentals of Network Biology. World Scientific Europe, London, UK. http://www.worldscientific.com/worldscibooks/10.1142/q0149

Zhang WJ. 2018b. Global pesticide use: Profile, trend, cost / benefit and more. Proceedings of the International Academy of Ecology and Environmental Sciences, 8(1): 1-27. http://www.iaees.org/publications/journals/piaees/articles/2018-8(1)/global-pesticide-use-Profile-trend-cost-benefit.pdf

Zhang WJ. 2019. Analytic Hierarchy Process (AHP): Matlab computation software. Network Biology, 9(1): 10-17. http://www.iaees.org/publications/journals/nb/articles/2019-9(1)/Analytic-Hierarchy-Process-Matlab-computation-software.pdf

Zhang WJ. 2024a. SampSizeCal: The platform-independent computational tool for sample sizes in the paradigm of new statistics. Network Biology, 14(2): 100-155. http://www.iaees.org/publications/journals/nb/articles/2024-14(2)/5-Zhang-Abstract.asp

Zhang WJ. 2024b. Structure comparison and evenness test of biological communities: Several platform-independent computational tools. Computational Ecology and Software, 14(2): 119-135. http://www.iaees.org/publications/journals/ces/articles/2024-14(2)/structure-comparison-evenness-test-biological-communities.pdf

Zhang WJ, Qi YH. 2025. probDistriCal: The online calculator for probability distributions. Computational Eco logy and Software, 15(2): 57-77. http://www.iaees.org/publications/journals/ces/articles/2025-15(2)/3-Zhang-Abstract.asp

Zhang WJ, Jiang FB, Ou JF. 2011. Global pesticide consumption and pollution: with China as a focus. Proceedings of the International Academy of Ecology and Environmental Sciences, 1(2): 125-144. http://www.iaees.org/publications/journals/piaees/articles/2011-1(2)/Global-pesticide-consumption-pollution.pdf

Zhang WJ, Liu GH. 2023. A dynamic model to simulate the development of insecticide resistance. Computational Ecology and Software, 13(3): 52-70. http://www.iaees.org/publications/journals/ces/articles/2023-13(3)/dynamic-model-to-simulate-development-of-insecticide-resistance.pdf

Zhang WJ, Pang Y. 2009. Impact of IPM and Transgenics in the Chinese Agriculture. In: Integrated Pest Management: Dissemination and Impact (Peshin R, Dhawan AK, eds). Springer, Netherlands. https://link.springer.com/chapter/10.1007%2F978-1-4020-8990-9_18

Zhang WJ, Pang Y, Qi YH, Chen QJ. 1997. Simulation model for epizootic disease of *Spodoptera litura* F. baculovirus. ACTA SCIENTIARUM NATURALIUM, 36(1): 54-59

Zhang WJ, Qi YH. 2024. ANOVA-nSTAT: ANOVA methodology and computational tools in the paradigm of new statistics. Computational Ecology and Software, 14(1): 48-67. http://www.iaees.org/publications/journals/ces/articles/2024-14(1)/4-Zhang-Abstract.asp

Zhang WJ, Qi YH, Gu DX. 1996. Objective system and benefit evaluation for microbial control of pests. Journal of Biomathematics, 11(5): 43-51