Caspian Journal of Environmental Sciences
Online ISSN: 1735-3866
Print ISSN: 1735-3033

Bund flora in the traditional rice paddy terraces in some foothill landscapes of Guilan Province, N. Iran, towards conservation of phytodiversity in agroecosystems

Maryam Ashouri*[1], Alireza Naqinezhad[2,3], Akbar Norastehnia[1]

1. Department of Biology, Faculty of basic Sciences, University of Guilan, Rasht, Iran
2. Department of Plant Biology, Faculty of Basic Sciences, University of Mazandaran, Babolsar, Iran
3. Department of Environmental Sciences, College of Science and Engineering, University of Derby, Kedleston Road, Derby, DE22 1GB, United Kingdom

** Corresponding author's E-mail: M_ashouri@phd.guilan.ac.ir*

ABSTRACT

One of the most important drivers of floristic biodiversity in the agricultural landscapes is semi-natural edge habitats. Rice paddy terraces are mostly found in the foothills and sub-montane parts of Iran's northern provinces, whereas rice is mostly farmed in the country's lowlands. The present study provides information on the floristic distribution of rice-terraced paddy bunds in the foothill areas of northern Iran. A total of 121 species, representing 29 families of vascular plants were recorded. Therophytes (50.4%) were the most frequent life forms, indicating typical ruderal vegetation and environmental disturbances. The most dominant chorotypes of recorded species were pluri-regional (53.7%) and cosmopolitan (15.7%) elements. In terms of conservation status, there are five species on the IUCN Red List that are mainly classified in the "least concern" category. Alien species are estimated to comprise 19.8 % of the flora. The results of the current study can be used as a scientific backbone for developing agricultural landscape management and conservation plans in Iran.

Keywords: Agro-landscape, Alien species, Guilan Province, Marginal habitat, Rice fields.
Article type: Research Article.

INTRODUCTION

Agricultural landscapes are among the most common and important ecosystems on the planet, with prevailing cropping systems containing varying-sized patches of less-managed uncropped regions like grasslands, forests, or wetlands (Bennett *et al.* 2021; Haan *et al.* 2021; Mueller *et al.* 2021). These landscapes are the outcome of interactions between farming operations and the surrounding natural environment (Kizos & Vlachos 2012) and cover about 40% of our planet's total terrestrial surface area and supply more than just a food source (Montoya *et al.* 2020). They also provide a variety of ecosystem services, such as erosion and flooding control, pollinator habitat, carbon sequestration, cultural heritage, and aesthetic perception (Bennett *et al.* 2021). The existence of natural areas, or landscape heterogeneity, and enhancing habitat quality is widely recognized for supporting species diversity and providing ecosystem services in agricultural landscapes. Agricultural spread and intensive management may have resulted in high crop yields during the last half-century, but it has also led to a reduction of diversity and functionality by simplifying habitats and landscapes (Cardarelli & Bogliani 2014; Vanbergen *et al.* 2020). Rice is an annual plant native to Asia and Africa, and it is now grown under various climatic conditions, from temperate to tropical, with different hydrological conditions and soil types across 116 countries (Datta *et al.* 2017; FAOSTAT 2019). Paddy terraces are stair-like fields for the irrigated cultivation of rice and have been constructed on the sloped terrains of hilly and mountainous regions (Mori *et al.* 2019; Chen *et al.* 2021). These agro-ecosystems, which are one of the most outstanding agricultural landscapes, are well known in Asian countries (Koyanagi *et al.* 2014; Chen *et al.* 2018; Everard 2018). Semi-natural grasslands surrounding paddy terraces are found between paddies (also referred to as bunds, dikes, or levees) and other features, including irrigation ditches or woodlands. They are built and maintained to keep water in the paddies while also functioning as footpaths and transportation, as well as defining the boundaries of possessions. Semi-natural grasslands can also serve as a refuge for agricultural landscapes to preserve natural vegetation. However, alien weed and pest species represent a threat to these semi-natural edge habitats (Bambaradeniya & Amerasinghe 2004; Matsumura & Takeda 2010; Uematsu & Ushimaru 2013; Koyanagi *et al.* 2014). Alien plant species have been introduced to new places as a result of human activities. They establish, thrive, and spread, outcompeting and affecting the native plants of the invaded region, which are species that have evolved in a specific area without human interference and are growing through natural means (Halmy 2019; Dehshiri 2021; Zhailybayeva *et al.* 2024). Cultivated lands are one of the centers for the alien species introduction, which has an impact on agricultural production and the surrounding ecosystem (Yamamoto & Kusumoto 2008; Memariani 2021; Ajamian *et al.* 2024). In particular, as mentioned above, the bund habitat of the rice production ecosystem is a good example of these centers. Although there have been extensive studies on the floristic composition and vegetation of paddies (Bolòs & Masclans 1955; Piccoli & Gerdol 1981; Turki & Sheded 2002; García & Benzal 2009; Nowak *et al.* 2013; Nowak *et al.* 2015; Nowak *et al.* 2016; Fried *et al.* 2017; Kim *et al.* 2019; Irakiza *et al.* 2021), little is known about the vegetation characteristics of paddy bunds (Fukamachi *et al.* 2005; Kawano *et al.* 2009; Matsumura & Takeda 2010; Uematsu & Ushimaru 2013; Koyanagi *et al.* 2014; Nemoto & Otsuka 2014; Fried *et al.* 2018). Iran has more than 600,000 ha of planted rice land, with over 80% concentrated in the two northern provinces, i.e., Mazandaran and Guilan (FAO 2019). Rice is grown predominantly in the lowlands of Iran. Paddy terraces, on the other hand, are only found in the north of the country, in the foothills and sub-montane areas. The aim of this study was to identify the floristic composition, life form, chorology, and endangered plant species of selected terrace paddies' bund habitats in Guilan Province, North Iran.

MATERIALS AND METHODS

Study area

The study area included terraced paddy fields located in the Rudbar and Rudsar counties, Guilan Province, Northern Iran (Fig. 1). The province is divided into two different regions based on altitude: the lowlands, which are adjacent to the Caspian Sea, and the mountainous sector, which covers over 70% of the province's total territory. The plains, or coastal lowlands, which are located at an altitude of less than 100 m above sea level, are the most important rice farming centers in the province. However, leveling and terracing are used to a lesser extent in the province's mountainous and sloping areas to produce rice (Eghbal *et al.* 2012). The summers in Guilan Province are hot and humid, while the winters are generally mild, with average monthly temperatures ranging from 3 ℃ in January to 30 ℃ in July. The mean annual precipitation is about 1506 mm, with October to December receiving 41% of the annual rainfall (Ashrafzadeh *et al.* 2016). The sampling sites range in elevation from 259 m to 394 m above sea level. Herbicide application in paddy levees is uncommon, and weeding is mostly done by hand.

Data collection

Vegetation was surveyed in paddy fields bunds and other surrounding grasslands during spring and summer 2018–2020. The voucher specimens were preserved in the herbarium of Guilan University (GUH). Flora Iranica (Rechinger 1963–2010), Flora of Iran (Assadi *et al.* 1988-2018), and Flora China (http://www.efloras.org; accessed 2021) are used for plant identification. The names of scientific plant taxa were standardized in accordance with The Plant List (http://www.theplantlist.org, viewed 2 October 2021) and International Plant Name Index (http://www.ipni.org, viewed 2 October 2021). Life-forms were determined according to Raunkiaer's classification (1934), and geographical distribution was based on Zohary (1973), Takhtajan (1986), and Léonard (1989). In the present study, the following abbreviations were used: ES (plants distributed in the Euro-Siberian region), IT (plants distributed in the Irano-Turanian region), M (plants distributed in the Mediterranean region), PL (pluri-regional elements, plants that cover over three of the above-mentioned phytogeographical regions); and COS (cosmopolitan refers to plants that are distributed all over the world). The IUCN Red List Categories were used to assess threatened species in the study area (IUCN 2021). The identification of non-native plants was based on the Global Naturalized Alien Flora (GloNAF, http://www.glonaf.org, viewed 14 October 2021; Van Kleunen *et al.* 2019), the Global Register of Introduced and Invasive Species (GRIIS http://www.griis.org, viewed 14 October 2021) databases, the above Flora Books, and all other floristic literature accessible.

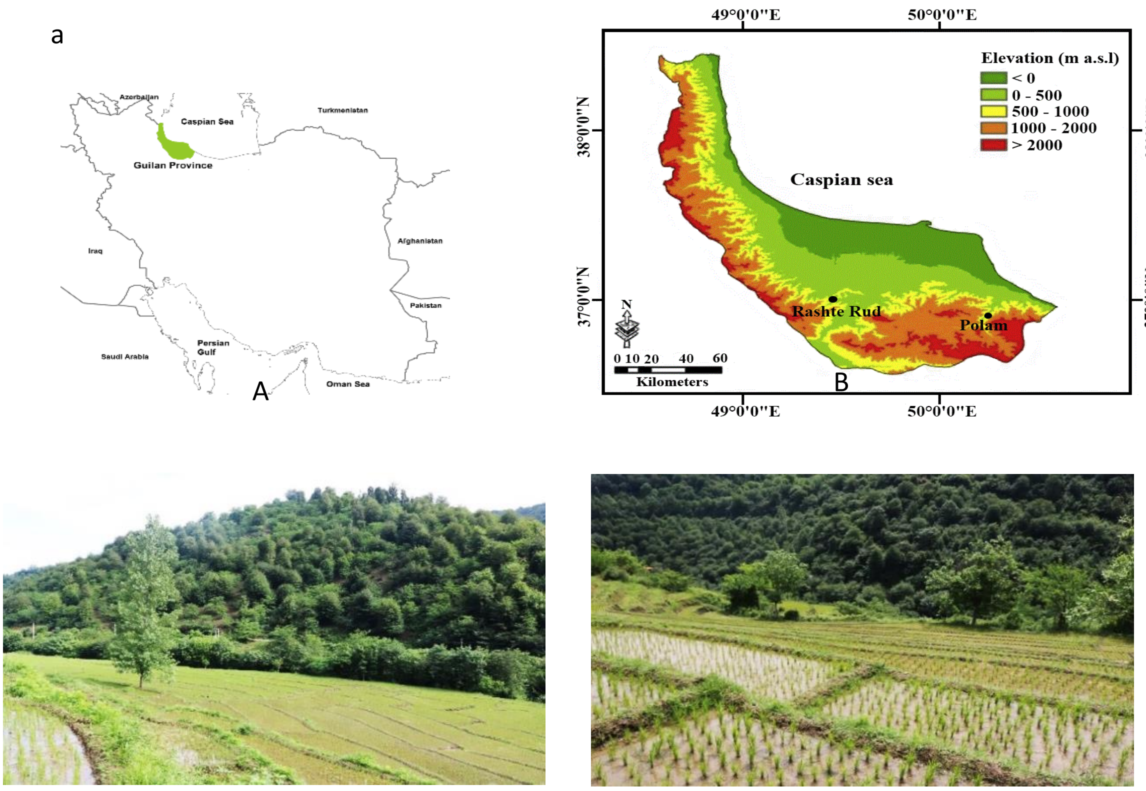

Fig. 1. Map of the study area with the location in Iran (A) and topography of Guilan Province (B; Source: Ashrafzadeh *et al.* 2016) and the traditional terrace landscapes: Polam village, Rudsar (C), Rashte-Rud village, Rudbar (D; photos by authors)

C D

RESULTS

A total of 121 species of vascular plants were identified from terraced paddies bunds, and other adjacent vegetation, belonging to 29 families and 84 genera (Appendix 1). The most represented families were Poaceae (19 taxa, 15.7%), Asteraceae (15 taxa, 12.4%), Fabaceae (12 taxa, 9.9%) and Cyperaceae (10 taxa, 8.3%). The genera with the most taxa were *Cyperus* (8), *Trifolium* (7), and *Rubus* (4). The most prevalent living forms were therophytes, which account for 50.4 % (61 taxa) of the investigated flora, followed by hemicryptophytes (27 taxa, 22.3%) and geophytes (19 taxa, 15.7%) (Fig. 2a). The chorological spectrum revealed pluri-regional (65 taxa, 53.7%) and cosmopolitan (19 taxa, 15.7%) elements with the most distribution in the area (Fig. 2b). Five taxa were Hyrcanian (sub) endemics, all of which were classified as "least concern" on the IUCN red list. (Table 1). Furthermore, the contribution of alien taxa was 19.8%, of which 5.8% was invasive. Five taxa were Hyrcanian (sub) endemics and red listed by IUCN, all in the "least concern" category (Table 1). The paddy bund habitats of the studied traditional rice paddies represent relatively a high species pool. Several exotic species are present in our research area. With the expansion of agriculture, dense human activities, and environmental degradation during the last 200 years, the detrimental impacts of non-native plant species around the world have increased (Shimura *et al.* 2010). Invasive alien species induce vegetative homogenization, community boundary modifications, and biodiversity loss. Because invasive alien species are often highly competitive, they have a negative impact on ecosystem function as well as significant economic consequences (Pungar *et al.* 2021). In our study, natives have been recorded more than aliens. However, the loss of native species diversity and the effects of aliens, particularly invasive taxa, should be monitored on a regular basis in order to achieve sustainable management on these farmlands (Rai 2020). Agricultural landscapes, like natural areas, have a high potential for biodiversity due to the different habitat types (Waide *et al.* 1999). Generally, the rice ecosystem is structurally made up of three components: (i) flooded paddy, (ii) paddy levee, and (iii) irrigation canals and ditches, each supports microhabitats with distinct vegetation and ecological functions (Matsumura *et al.* 2014; Choi *et al.* 2021).

Paddies are highly managed anthropogenic habitats characterized by tillage, flooding, and extended herbicide application, resulting in a species-poor and uniform flora (Miyawaki 1960; Kim *et al.* 2019).

Table 1. (Sub) endemic Hyrcanian species of the research area. All taxa are listed by IUCN in the "least concern" category.

Family	Taxa
Lamiaceae	*Teucrium hyrcanicum*
Polygonaceae	*Polygonum hyrcanicum*
Rosaceae	*Rubus hyrcanus*
	Rubus persicus
Rubiaceae	*Phuopsis stylosa*

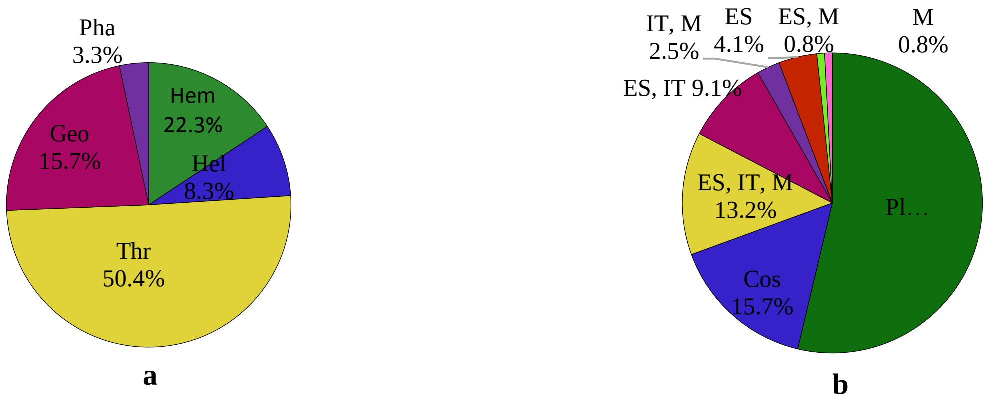

Fig. 2. Life form (a) and chorological (b) spectra in the paddy terrace landscapes of Guilan Province. Abbreviations: a) Thr: Therophyte, Hem: Hemicryptophytes, Pha: Phanerophytes, Hel: helophytes, Geo: geophyte. b) Pl: Pluri-regional, Cos: Cosmopolitan elements, IT: Irano-Turanian elements, M: Mediterranean elements, ES: Euro-Siberian.

In contrast, several studies have found that the flora and vegetation on levees differ and are more diverse than in paddy habitats (Bambaradeniya *et al.* 2004; Nemoto & Otsuka 2014; Kumalasari & Bergmeier 2014; Fried *et al.* 2018). Bund plant communities are mostly terrestrial, but in the early stages of the rice cultivation cycle, aquatic plants and, prior to harvesting, terrestrial plants thrive in paddies. Traditional levees are important in our terrace paddies to maintain the plant biodiversity of the surrounding semi-natural elements. Due to the slopes of the topography, terrace paddy fields have lower paddy sizes and broader levees than lowland paddy fields (Miyashita *et al.* 2014). For biological control and integrated pest management, the well-managed vegetation of the bund may provide a valuable habitat for natural enemies of rice pests. However, they can be important entry points for weed seeds or propagules into the paddy if not properly maintained (Rao *et al.* 2017). Tertiary relict tree species or seedlings (Akhani *et al* .2010; Naqinezhad *et al* .2022), such as *Alnus subcordata*, *Gleditsia capsica*, and *Parrotia persica*, can be found scattered in some parts of our investigated bunds, between forest and paddies. This woody vegetation makes hedgerows for agricultural systems (Burel 1996). Hedgerows reduce water and wind erosion by deterring surface runoff and acting as effective windbreaks to protect surrounding fields from severe weather, respectively. They provide a diverse habitat for many plant species while also integrating other fragmented forest ecosystems and maintaining biodiversity (Litza *et al*. 2022). Despite the importance of hedgerows, farmers destroy them by cutting the trees to avoid disease or insect infestations and shade for the rice. The predominance of therophytes in the bund flora of this study highlights adaptations to strong disturbances such as frequent trampling. Studies by Kawano *et al.* (2009) in Japan and Fried *et al.* (2018) in Vietnam and the Philippines' paddy bund of agricultural systems have confirmed the present findings. Plant survival strategies with burning or mowing are represented by the biological spectra of geophytes and hemicryptophytes (Kawano *et al.* 2008). Studies of the geographical distribution of plants are very important for biodiversity conservation and management (Zeb *et al.* 2021). The high proportion of pluri-regional and cosmopolitan taxa in the current research is attributed to weeds and ruderal species in the vegetation (Akhani *et al*. 2010), indicating substantial human influences.

CONCLUSION

This research examined the vegetation bunds in the rice terrace agro-ecosystems in Northern Iran. Bund habitat has a moderate level of human intervention, resulting in a dynamic vegetation in which both human and environmental variables influence species persistence (Pitkänen *et al.* 2016). The results from this study should be considered to establish management schemes to conserve these valuable habitats. We recommend that future studies be conducted on the paddy bund vegetation and compare the results with other similar ecosystems. The conservation of rare and endangered species, assessing the presence and implications of aliens in order to promote ecological resilience and the improvement of ecosystem services are the major objectives of these initiatives. We came to the conclusion that preserving the biodiversity of these semi-natural habitats, along with agricultural regions, would enhance overall biodiversity maintenance and support.

ACKNOWLEDGEMENTS

This paper is dedicated to the memory of Dr. Shahryar Saeidi Mehrvarz, professor of botany at the University of Guilan. The authors would like to express their thank to the farmers who graciously permitted them access to their land. We appreciate all the support of the Guilan Province Agricultural Jihad Organization during the sampling interval.

REFERENCES

Ajamian, M, Beygom Faghir, M, Bazdid Vahdati, F 2024, Floristic, life form and chorological studies of the Saqalaksar forest, Rasht, Northern Iran. *Caspian Journal of Environmental Sciences*, 22: 277-288.

Akhani, H, Djamali, M, Ghorbanalizadeh, A & Ramezani, E 2010, Plant biodiversity of Hyrcanian relict forests, N Iran: An overview of the flora, vegetation, palaeoecology and conservation. *Pakistan Journal of Botany*, 42: 231-248.

Ashrafzadeh, A, Roshandel, F, Khaledian, M, Vazifedoust, M & Rezaei, M 2016, Assessment of groundwater salinity risk using kriging methods: a case study in northern Iran. *Agricultural Water Management*, 178: 215-224.

Assadi, M, Maassoumi, AA, Khatamsaz, M & Mozaffarian, V 1988-2018, Flora of Iran, Vols. 1-147. Research Institute of Forests and Rangelands Publications, Tehran. [In Persian].

Bambaradeniya, CNB & Amerasinghe, FP 2004, Biodiversity associated with the rice field agroecosystem in Asian countries: A brief review. *International Water Management Institute*, 63: 1-24.

Bambaradeniya, CNB, Edirisinghe, JP, De Silva, DN, Gunatilleke, CVS, Ranawana, KB & Wijekoon, S 2004, Biodiversity associated with an irrigated rice agro-ecosystem in Sri Lanka. *Biodiversity and Conservation,* 13: 715-1753.

Bennett, EM, Baird, J, Baulch, H, Chaplin-Kramer, R, Fraser, E, Loring, P, Morrison, P, Parrott, L, Sherren, K, Winkler, KJ, Cimon-Morin, J, Fortin, M-J, Kurylyk, BL, Lundholm, J, Poulin, M, Rieb, JT, Gonzalez, A, Hickey, GM, Humphries, M & Lapen, D 2021, Ecosystem services and the resilience of agricultural landscapes, in DA Bohan & AJ Vanbergen (eds), Advances in ecological research. Academic Press Inc., Cambridge.

Bolōs, OD & Masclans, F 1955, La vegetación de los arrozales en la región mediterránea [The vegetation of rice fields in the Mediterranean region]. *Collectanea Botanica*, 4: 415-434 (In Spanish with English Abstract).

Burel, F 1996, Hedgerows and their role in agricultural landscapes. *Critical Reviews in Plant Sciences*, 15: 169-190.

Cardarelli, E & Bogliani, G 2014, Effects of grass management intensity on ground beetle assemblages in rice field banks. *Agriculture, Ecosystems & Environment*, 195: 120-126.

Chen, B, Qiu, Z, Usio, N & Nakamura, K 2018, Conservation and contingent valuation of farming landscape amenities by visitors: A case study of terraced paddy fields in Central Japan. *Paddy Water Environment*, 16: 561-570.

Chen, D, Wei, W & Chen, L 2021, Effects of terracing on soil properties in three key mountainous regions of China. *Geography and Sustainability*, 2: 195-206.

Chivenge, P, Angeles, O, Hadi, B, Acuin, C, Connor, M, Stuart, A, Puskur, R & Johnson-Beebout, S 2020, Ecosystem services in paddy rice systems. In L, Rusinamhodzi (ed), The role of ecosystem services in sustainable food systems, Academic Press, Cambridge.

Choi, G, Do, MS, Son, SJ & Nam, HK 2021, Effect of different management techniques on bird taxonomic groups on rice fields in the Republic of Korea. *Scientific Reports*, 11: 1-10.

Datta, A, Ullah, H & Ferdous, Z 2017, Water Management in Rice. In: BS, Chauhan, K, Jabran & G, Mahajan (eds, Rice Production Worldwide, Springer, Cham.

Dehshiri, MM 2021, Invasive alien species of Iran. In: T, Pullaiah & MR, Ielmini (eds), Invasive alien species: Observations and issues from around the world, John Wiley & Sons.

Eghbal, M, Givi, J, Torabi, H & Miransari, M 2012, Formation of soils with fragipan and plinthite in old beach deposits in the South of the Caspian Sea, Guilan Province, Iran. *Applied Clay Science*, 64: 44-52.

Everard, M 2018, Rice paddies. In: CM, Finlayson *et al.* (eds), The Wetland Book, Springer, Dordrecht.

FAO, 2019, The state of the world's biodiversity for food and agriculture, viewed 17 May 2021, <http://www.fao.org/3/w8595t/w8595t05.htm.

FAOSTAT, 2019, FAOSTAT Online Database, viewed May 2, 2021, <http://www.fao.org/faostat/en/#data.

Fried, O, Kühn, I, Schrader, J, Nguyen, VS & Bergmeier, E 2017, Plant diversity and community composition of rice agroecosystems in Vietnam and the Philippines. *Phytocoenologia*, 47: 49-66.

Fried, O, Kühn, I, Schrader, J, Nguyen, VS & Bergmeier, E 2018, Plant diversity and composition of rice field bunds in Southeast Asia. *Paddy and Water Environment*, 16: 359-378.

Fukamachi, K, Oku, H & Miyake, A 2005, The relationships between the structure of paddy levees and the plant species diversity in cultural landscapes on the west side of Lake Biwa, Shiga, Japan. *Landscape and Ecological Engineering*, 1: 191-199.

García, PV& Benzal, AV 2009, Flórula y vegetación de "Els Ullals de Na Molins" (La Albufera. Valencia). Referencia de un estado intermedio de restauración de humedales [Flora and vegetation of "Els Ullals de Na Molins" (La Albufera. Valencia). Reference for an intermediate state of wetland restoration], *Flora Montiberica*, 42: 31-40 [In Spanish].

Haan, NL, Iuliano, BG, Gratton, C & Landis, DA, 2021, Designing agricultural landscapes for arthropod-based ecosystem services in North America. In: D, Bohan & A, Vanbergen (eds.), The future of agricultural landscapes, Part II, Academic Press, Massachusetts.

Halmy, MWA, Fawzy, M, Ahmed, DA, Saeed, NM & Awad, MA 2019, Monitoring and predicting the potential distribution of alien plant species in arid ecosystem using remotely-sensed data. *Remote Sensing Applications: Society and Environment*, 13: 69-84.

Irakiza, RW, Makokha, D, Malombe, IL, Bourgeois, TK, Chitiki, A & Rodenburg, J 2021, Composition of weed communities in seasonally flooded rice environments in East Africa is determined by altitude. *South African Journal of Botany*, 140: 143-152.

IUCN 2021, The IUCN Red List of threatened species. Version 2021-1, viewed 2 May 2021, <https://www.iucnredlist.org.

IUCN, 2019, Guidelines for using the IUCN red list categories and criteria. Version 14.

Kawano, N, Fukuzumi, S, Umemori, K, Ishikawa, S & Miyake, N 2008, Relationship between management regime and species diversity of the semi-natural grasslands in the Shiodzuka highlands, Shikoku, Western Japan. *Hikobia*, 15: 205-215. (In Japanese with English Abstract).

Kawano, N, Kawano, K, Ohsawa, M 2009, Floristic diversity and the richness of locally endangered plant species of seminatural grasslands under different management practices, southern Kyushu, Japan. *Plant Ecology and Diversity*, 2: 277-288.

Kim, SY, Kim, MS, Ryu, YM & An, SL 2019, A phytosociological study of spring-type rice field vegetation, Angye Plains, South Korea. *Journal of Asia-Pacific Biodiversity*, 12: 661-667.

Kizos, T & Vlachos, G 2012, The evolution of the agricultural landscape. In: T, Papayiannis & P, Howard (eds.), Reclaiming the Greek landscape, MED-INA, Athens.

Koyanagi, TF, Yamada S, Yonezawa, K, Kitagawa, Y & Ichikawa, K 2014, Plant species richness and composition under different disturbance regimes in marginal grasslands of a Japanese terraced paddy field landscape. *Applied Vegetation Science*, 17: 636-644.

Kumalasari, NR & Bergmeier, E 2014, Effects of surrounding crop and semi-natural vegetation on the plant diversity of paddy fields. *Agriculture & Food Security*, 3: 1-8.

Léonard, J 1989, Contribution a l'etude de la flore et de la vegetation des deserts d'Iran [Contribution to the study of flora and vegetation of deserts of Iran). Vol. 9, Jardin Botanique National de Belgique, Meise.

Litza, K, Alignier, A, Closset-Kopp, D, Ernoult, A, Mony, C, Osthaus, M, Staley, J, Van Den Berge, S, Vanneste, T & Diekmann, M, 2022, Hedgerows as a habitat for forest plant species in the agricultural landscape of Europe. *Agriculture, Ecosystems and Environment*, 326: 107809.

Matsumura, T & Takeda, Y 2010, Relationship between species richness and spatial and temporal distance from seed source in semi-natural grassland. *Applied Vegetation Science*, 13: 336-345.

Matsumura, T, Uchida, K & Sawada, Y 2014, Conditions and conservation for biodiversity of the semi-natural grassland vegetation on rice paddy levees. *Vegetation Science*, 31: 193-218. (In Japanese with English Abstract).

Memariani, F 2020, The Khorassan-Kopet Dagh Mountains, In: J, Noroozi (ed), Plant Biogeography and Vegetation of High Mountains of Central and South-West Asia, Springer, Cham.

Miyashita, T, Yamanaka, M & Tsutsui, MH 2014, Distribution and abundance of organisms in paddy-dominated landscapes with implications for wildlife-friendly farming. In: N, Usio & T, Miyashita (eds.), Social-ecological restoration in paddy-dominated landscape, Springer, Tokyo.

Miyawaki, A 1960, Pflanzensoziologische untersuchungen über reisfeld-vegetation auf den Japanischen Inseln mit vergleichender betrachtung mitteleuropas [Plant-sociological studies of rice field vegetation on the Japanese Islands with a comparative view of Central Europe], Vegetatio Acta Geobot, 9: 345-402 (In German with English Abstract).

Montoya, D, Gaba, S, de Mazancourt, C, Bretagnolle, V, Loreau, M 2020, Reconciling biodiversity conservation, food production and farmers' demand in agricultural landscapes. *Ecological Modelling*, 416: 108889.

Mori, Y, Sasaki, M, Morioka, E & Tsujimoto, K 2019, When do rice terraces become rice terraces? *Paddy Water Environment*, 17: 323-330.

Mueller, L, Eulenstein, F, Mirschel, W, Schindler, U, Sychev, VG, Rukhovich, OV & Dronin, NM 2021, Optimizing agricultural landscapes: Measures towards prosperity and sustainability. In: L, Mueller *et al.* (eds.), Exploring and optimizing agricultural landscapes, innovations in landscape research, Springer, Cham.

Naqinezhad, A, De Lombaerde, E, Gholizadeh, H, Wasof, S, Perring, MP, Meeussen, C, De Frenne, P & Verheyen, K 2022, The combined effects of climate and canopy cover changes on understory plants of the Hyrcanian forest biodiversity hotspot in Northern Iran. *Global Change Biology*, 28: 1103-1118.

Nemoto, M & Otsuka, H 2014, influence of farming system on the floristic composition of paddy landscapes: a case study in a rural hilly zone in Zhejiang province, China. *Landscape and Ecological Engineering*, 10: 173-180.

Nowak, A, Nowak, S & Nobis, M 2015, First insights into weed communities of rice agrocoenoses in Southern Thailand. *Phytocoenologia*, 45: 157-174.

Nowak, A, Nowak, S & Nobis, M 2016, Spring weed communities of rice agrocoenoses in Central Nepal. *Acta Botanica Croatica*, 75: 99-108.

Nowak, S, Nowak, A & Nobis, M 2013, Weed communities of rice fields in the central Pamir Alai Mountains (Tajikistan, Middle Asia). *Phytocoenologia*, 43: 101-126.

Piccoli, F & Gerdol, R 1981, Rice-field weed communities in Ferrara Province (Northern Italy). *Aquatic Botany*, 10: 317-328.

Pitkänen, TP, Kumpulainen, J, Lehtinen, J, Sihvonen, M & Käyhkö, N 2016, Landscape history improves detection of marginal habitats on semi-natural grasslands. *The Science of the Total Environment*, 539: 359-369.

Pungar, D, Bunce, RGH, Raet, J, Kaart, T & Sepp, K 2021, A survey of habitats on agricultural land in Estonia II. Detailed interpretation of the habitats' landscape ecology and how this relates to alien plant species. *Global Ecology and Conservation*, 27: e01568.

Rai, PK & Singh, JS 2020, Invasive alien plant species: Their impact on environment, ecosystem services and human health. *Ecological Indicators*, 111: 106020.

Rao, AN, Wani, SP, Ramesha, MS & Ladha, JK 2017, Rice production systems. In: BS, Chauhan, K, Jabran & G, Mahajan (eds.), Rice production worldwide, Springer, Switzerland.

Raunkiaer, C 1934, The life form of plants and statistical plant geography. Clarendon Press, Oxford.

Rechinger, KH (ed.) 1963-2010, Flora Iranica, Vols. 1-167, Akad. Druck- and Verlagsanstalt, Graz.

Shimura, J, Coates, D & Mulongoy, JK 2010, The role of international organizations in controlling invasive species and preserving biodiversity. *Revue Scientifique et Technique*, 29: 405-410.

Takhtajan, A 1986, Floristic regions of the World, University of California Press, Berkeley.
Turki, Z & Sheded, M 2002, Some observations on the weed flora of rice fields in the Nile Delta, Egypt. *Feddes Repertorium,* 113: 394-403.
Uematsu, Y & Ushimaru, A 2013, Topography- and management-mediated resource gradients maintain rare and common plant diversity around paddy terraces. *Ecological Applications*, 23: 1357-1366.
Vanbergen, AJ, Aizen, MA, Cordeau, S, Garibaldi, LA, Garratt, MPD, KovácsHostyánszki, A, Lecuyer, L, Ngo, HT, Potts, SG, Settele, J, Skrimizea, E & Young, JC 2020, Transformation of agricultural landscapes in the Anthropocene: Nature's contributions to people, agriculture and food security. *Advances in Ecological Research,* 63: 193-253.
Waide, RB, Willig, MR, Steiner, CF, Mittelbach, G, Gough, I, Dodson, SI, Juday, GI & Parmenter, R 1999, The relationship between productivity and species richness. *Annual Review of Ecology and Systematics*, 30: 257-300.
Yamamoto, S and Kusumoto Y 2008, An Application of Rural Landscape Information System for Assessment of Alien Plant Species in Paddy Landscape in Japan, International seminar on management of major emerging plant pests in agriculture in the Asia and pacific region. Food and Fertilizer Technology Center, Taipei, pp. 1-7.
Zeb, SA, Khan, SM & Ahmad, Z 2021, Phytogeographic elements and vegetation along the River Panjkora-classification and ordination studies from the Hindu Kush Mountains Range. *The Botanical Review*, 25: 1-25.
Zhailybayeva, TM, Iskakovich, SK, Duisengalievna, MA, Kunsalievna, MB, Nurakhmetovna, AR, Aigul, B 2024, Flora of the gorges Merke, Sandyk, Shaisandyk in the western part of Kyrgyz Alatau, a natural border between Kyrgyzstan and Kazakhstan. Caspian Journal of Environmental Sciences, 22: 59-69.
Zohary, M 1973, Geobotanical foundations of the Middle East, Fischer, Stuttgart.

Appendix 1

List of recorded species in the surrounding semi-natural vegetation of terrace paddies of Guilan Province during the years 2018-2019. abbreviations used, Life forms: Geo geophyte, Hel helophyte, Hem hemicryptophyte, Pha phanerophyte, Thr therophyte; Chorotypes: Cos cosmopolitan, ES EuroSiberian, Hyr hyrcanian, IT Irano-Turanian, M Mediterranean, Pl pluri-regional; Status: Al alien, In invasive, Na native.

Taxa	Life form	Chorotype	Status
Monilophytes			
Dennstaedtiaceae			
Pteridium aquilinum (L.) Kuhn.	Geo	Cos	Al/In
Angiosperms			
Eudicots			
Adoxaceae			
Sambucus ebulus L.	Geo	ES, IT, M	Na
Amaranthaceae			
Alternanthera sessilis R.Br.	Thr	Pl	Al
Amaranthus lividus L.	Thr	Pl	Na
Amaranthus retroflexus L.	Thr	Pl	Al
Amaranthus viridis L.	Thr	Pl	Al
Chenopodium album L.	Thr	Cos	Al
Apiaceae			
Pimpinella affinis Ledeb.	Hem	Pl	Na
Berula erecta (Huds.) Coville	Hel	Pl	Na
Centella asiatica (L.) Urban	Hem	ES, IT	Na
Cyclospermum leptophyllum (Pers.) Sprague	Thr	Pl	Al
Torilis heterophylla Guss.	Thr	Pl	Na
Torilis leptophylla (L.) Gaertn.	Thr	Pl	Na
Asteraceae			
Anthemis cotula L.	Thr	Pl	Na
Artemisia annua L.	Thr	ES, IT, M	Na
Artemisia vulgaris L.	Hem	Pl	Na
Bidens tripartita L.	Thr	Pl	Na
Centaurea iberica Trev. ex Spreng.	Thr	Pl	Na
Conyza bonariensis (L.) Cronq.	Thr	Cos	Al
Conyza canadensis (L.) Cronquist	Thr	Cos	Al
Conyzanthus squamatus (Spreng.) Tamamsch.	Hem	Pl	Na
Crepis micrantha Czerep.	Thr	ES, IT, M	Na
Eclipta prostrata (L.) L.	Thr	Pl	Al
Erigeron annuus (L.) Pers.	Thr	Pl	Na
Lapsana communis L.	Hem	ES, IT	Na
Sonchus asper (L.) Hill. subsp. *glaucescens* (Jordan) Ball	Hem	Pl	Na
Sonchus oleraceus L.	Thr	Pl	Na
Xanthium strumarium L.	Thr	Pl	Al
Boraginaceae			
Myosotis Palustris (L.) Nathh.	Geo	Cos	Na
Brassicaceae			
Cardamine hirsuta L.	Thr	Cos	Na
Nasturtium officinale W.T. Aiton	Hel	Pl	Na
Rorippa islandica (Oeder) Borbás	Geo	Pl	Na
Caryophyllaceae			
Cerastium glomeratum Thuill.	Thr	Cos	Na
Cerastium semidecandrum L.	Thr	ES, IT, M	Na
Stellaria media Cirillo	Thr	Cos	Al/In
Convolvulaceae			
Calystegia sepium (L.) R.Br.	Geo	Pl	Na
Euphorbiaceae			
Acalypha australis L.	Thr	Pl	Al
Euphorbia helioscopia L.	Thr	ES, IT, M	N
Euphorbia maculata L.	Thr	Pl	Al
Fabaceae			
Medicago lupulina L.	Thr	Pl	Na
Medicago minima (L.) L.	Thr	Pl	Na
Medicago polymorpha L.	Thr	IT, M	Na
Melilotus indicus L. (All.)	Thr	Pl	Na
Securigera varia (L.) Lassen.	Thr	ES, IT, M	Na
Trifolium arvense L.	Thr	Pl	Na

Trifolium campestre Schreb.	Thr	ES, IT, M	Na
Trifolium fragiferum L.	Geo	Pl	Na
Trifolium pratense L.	Hem	Pl	Na
Trifolium repens L. var. *repens*	Geo	ES, IT, M	Na
Trifolium resupinatum L.	Thr	ES, IT, M	Na
Trifolium scabrum L.	Thr	ES, M	Na
Geraniaceae			
Geranium dissectum L.	Hem	ES, IT	Al
Hypericaceae			
Hypericum perforatum L.	Hem	Cos	Na
Lamiaceae			
Calamintha officinalis Moench	Geo	ES, IT	Na
Lycopus europaeus L.	Geo	Pl	Na
Mentha aquatica L.	Hel	ES	Na
Mentha longifolia L.	Hem	Pl	Na
Prunella vulgaris (L.) L.	Geo	Pl	Na
Teucrium hyrcanicum Steud.	Geo	ES	Na
Lythraceae			
Ammannia baccifera L.	Hel	Pl	Na
Lythrum salicaria L.	Hem	Cos	Na
Onagraceae			
Epilobium hirsutum L.	Hem	Pl	Na
Ludwigia palustris (L.) Elliott	Hel	Cos	Na
Oxalidaceae			
Oxalis corniculata L.	Thr	Cos	Na
Phytolaccaceae			
Phytolacca americana L.	Hem	Pl	Na
Plantaginaceae			
Plantago major L.	Hem	Pl	Na
Veronica anagallis-aquatica L.	Hel	Pl	Na
Veronica polita L.	Thr	Cos	Na
Polygonaceae			
Persicaria lapathifolia (L.) S.F. Gray subsp. *lapathifolia*	Thr	ES, IT	Na
Polygonum aviculare L.	Thr	ES, IT	Al/In
Polygonum hyrcanicum Rech. F.	Thr	ES, IT	Na
Rumex sanguineus L.	Hem	ES, IT	Na
Rumex Pulcher L.	Hem	ES, IT, M	Na
Primulaceae			
Anagallis arvensis L. var. *arvensis*	Thr	Cos	Al
Centaurium pulchellum (Sw.) Druce	Thr	ES, IT, M	Na
Ranunculaceae			
Ranunculus marginatus d'Urv.	Thr	Pl	Na
Ranunculus muricatus L.	Thr	IT, M	Na
Ranunculus scleratus L**.**	Thr	Pl	Na
Rosaceae			
Agrimonia eupatoria L.	Hem	ES, IT, M	Na
Potentilla reptans L.	Hem	ES, IT, M	Na
Rubus caesius L.	Pha	ES, IT	Na
Rubus hyrcanus Juz.	Pha	ES (Hyr)	Na
Rubus persicus Boiss.	Pha	ES (Hyr)	Na
Rubus sanctus Schreb.	Pha	ES, IT	Na
Rubiaceae			
Galium ghilanicum Stapf.	Thr	ES, IT, M	Na
Galium humifusum M.B.	Geo	ES, IT, M	Na
Oldenlandia capensis var. *pleiosepala* Bremek.	Thr	M	Na
Phuopsis stylosa (Trin.) Hook.f. ex B.D. Jacks.	Geo	ES (Hyr)	Na
Verbenaceae			

Phyla nodiflora (L.) Greene	Hem	Pl	Na
Verbena officinalis L.	Hem	Pl	Na
Monocots			
Alismataceae			
Alisma plantago-aquatica L.	Hel	Pl	Na
Cyperaceae			
Cyperus difformis L.	Thr	Pl	Na
Cyperus esculentus L.	Geo	Cos	Al
Cyperus fuscus L.	Thr	Pl	Na
Cyperus glaber L.	Thr	Pl	Na
Cyperus longus L.	Geo	Pl	Na
Cyperus odoratus L. subsp. *transcaucasicus* (Kuk.) Kukkonen	Geo	ES, IT	Na
Cyperus rotundus L.	Geo	Cos	Na
Cyperus serotinus Rottb.	Hel	Pl	Na
Eleocharis uniglumis Schult.	Hel	Pl	Na
Fimbristylis bisumbellata (Forssk.) Bubani	Thr	Pl	Na
Juncaceae			
Juncus effusus L.	Geo	Cos	Na
Poaceae			
Alopecurus myosuroides Huds.	Thr	Pl	Na
Arthraxon hispidus (Thunb.) Makino var. *hispidus*	Thr	Pl	Al
Catabrosa aquatica (L.) P. Beauv.	Hel	Pl	Na
Cynodon dactylon (L.) Pers.	Hem	Pl	Al/In
Dactylis glomerata L.	Hem	Pl	Na
Digitaria sanguinalis (L.) Scop. subsp. *pectiniformis* Henrard	Thr	Pl	Na
Echinochloa colona (L.) Link.	Thr	Pl	Al
Echinochloa crus-galli (L.) P.Beauv.	Thr	Cos	Al/In
Eleusine indica (L.) Gaertn.	Thr	Pl	Al
Lolium perenne L.	Hem	Pl	Na
Lolium rigidum Gaudin	Thr	ES, IT, M	Na
Microstegium vimineum (Trin.) A. Camus	Hem	Pl	Na
Paspalum dilatatum Poir.	Hem	Pl	Al/In
Paspalum distichum L.	Hem	Cos	Al/In
Poa annua L.	Thr	Pl	Na
Poa trivialis L.	Hem	Pl	Na
Setaria glauca (L.) P. Beauv.	Thr	Pl	Na
Sorghum halepense Pers.	Geo	Pl	Na
Vulpia myuros (L.) C.C. Gmel.	Thr	IT, M	Na