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Marginal lands: a review of papers from the Scopus database published in English for the period of 1979–2022

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Abstract

A marginal land definition is a contemporary scientific term that is constantly changing and unstoppable. There are many ways in which marginal lands are referred to, unproductive lands, including waste lands, unutilized lands, idle lands, abandoned lands, or degraded land. In the present research, we tried to collect all Scopus-based publications in English from 1979 to 2022 years using crucial keywords: Marginal lands, Land degradation, and Agricultural land. We analyzed the most popular journals, top authors, top-cited papers, top countries, top-cited years, etc. A common way to identify ML is to use biophysical constraints related to agricultural productivity or bioenergy. For instance, using a multi-criteria decision approach based on Geographic Information Systems (GIS) and remote sensing, combined data on land use/land cover (LULC), slope, soil depth, erosion, moisture, water holding capacity, texture, and availability of nutrient to study the land suitability for agriculture in hilly zones. There is a high potential for applying remote sensing (RS) and geographical information systems (GIS) for the mapping and monitoring of marginal lands. In addition, the role of remote sensing (RS) and geographic information systems (GIS) in other disciplines around the world is significantly high. In contrast, in this research work, we find out that the usage scale of RS and GIS technologies is not common all around the world on the given marginal land issues.

1. Introduction

In the first place, the land provides food for humans. It is imperative to treat land resources as non-renewable resources (Tong et al., 2018). Soil is part of the land and is a finite resource that serves various purposes, such as producing food, feed, lumber, and fiber, as well as preserving the environment and protecting the climate by absorbing and storing carbon dioxide. Soil can absorb carbon sequestration and store carbon dioxide from the atmosphere which are plants absorb carbon dioxide during photosynthesis and store it in the soil as organic matter. As a result, good healthy soil will prevent climate change by reducing carbon dioxide in the atmosphere. Therefore, it is necessary to implement integrated policies for managing water, land use, and energy.

1.1. Marginal land concepts

The concept of marginal land is not new; Ricardo used it as a term in the 19th century in his Theory of Rent (Ricardo, 2005). The overall vision of the term "marginal land" was initially related to land uses that are not economically profitable (Carbonell-Rivera et al., 2021). Due to varying objectives, marginal land is defined differently by different regions, countries, and organizations (Tang et al., 2010; Wells et al., 2018). Although the concept of marginal land has been widely applied, there is a limited and diverse understanding and knowledge of marginal land as a concept, as well as its assessment and management (Arshad et al., 2021; Kang et al., 2013). There are many ways in which marginal lands are referred to, unproductive lands, including waste lands, unutilized lands, idle lands, abandoned lands, or degraded land (Wiegmann et al., 2008). The Food and Agricultural Organizations (FAO) and United Nations Environment Programme (UNEP) classified marginal land as that which supports only a yield of 40 percent of its productivity potential (Ahmadzai et al., 2021). Later, Peterson and Galbraith in 1932 introduced a dynamic method to determine the location of marginal lands by examining the major variables associated with marginal lands. Different backgrounds and concerns led to different usages of the terms physical marginal land, production marginal land, and economic marginal land (Peterson and Galbraith, 1932). As part of their land use planning, soil scientists and agronomists consider physical marginality of lands as well as production marginality, based on soil suitability and restrictions (Hart, 2001; Heimlich, 1989). Certain land constraints may not have a direct link with crop cultivation, particularly in the short run. Instances of such constraints include areas that are ecologically delicate or land that is susceptible to erosion and due to soil characteristics such as high acidity, salinity, or soil compaction may limit the land use planning (Lin, 2011). Marginal is an economic term originally used to describe places where cost-effective production is not rewarded under given conditions (Hollander, 1895; Peterson and Galbraith, 1932). It is also recognized that marginal lands are those where "cost-effective production cannot be achieved under current conditions, cultivation techniques, agricultural policies, and macroeconomic and legal circumstances" (Dauber et al., 2012). The other researchers expressed that marginal land is one where yields and prices barely compensate for the cost of production as a whole. There are however various factors that can affect this economic delineation, including the food price level, which can vary by a factor of two or even more from year to year. Kang et al. (2013) expressed that marginal lands are frequently characterized by poor economic return, low productivity, or strong restrictions on agricultural use. Generally speaking, they are vulnerable to the environment and delicate (Ciria et al., 2019; Hollander, 1895; Kang et al., 2013; Strijker, 2005).

Qureshi defined marginal environments as the areas where the salinization of land and water resources restrict potential crop production. ML have poor permeability, high salt contents, shallow water table conditions, and other associated problems which restrict agricultural production (Senior Scientist – Irrigation and Water Management, International Center for Biosaline Agriculture (ICBA), P.O. Box 14660, Dubai, UAE and Qureshi, 2017). According to Breuning-Masen, Reenberg, and Holst (1990), steep, wet, and droughty soils account for marginal agricultural land, which was mapped to depict marginal land areas (Breuning-Madsen et al., 1990). To detect the trend of abandonment of cultivation lands in Germany and identify marginal lands, recent satellite data and historical information were used (Reger et al., 2007). In China, marginal lands include wastelands, paddy fields, and winter fallow lands (Tang et al., 2010). South Australia's Marginal Lands Act 1940 simply describes marginal land as farmland that is used for wheat production, but not suitable for principle crop production due to insufficient rainfall (Marginal Lands Act 1940, 2002). It is therefore difficult to categorize or quantify marginal lands, resulting in considerable uncertainty when estimating their availability and suitability for bioenergy crops. ML also does not define a single method for identifying and classifying, and the available methods reflect management goals. In terms of physical characteristics (i.e., environmental factors), these methods range from those that focus purely on socioeconomic factors to those that focus purely on physical characteristics. A common way to identify ML is to use biophysical constraints related to agricultural productivity or bioenergy (Karlen et al., 1997; Bertaglia et al., 2007; Ciria et al., 2019; Torralba et al., 2021). For instance, using a multi-criteria decision approach based on Geographic Information Systems (GIS) and remote sensing, (Reger et al., 2007; Zolekar and Bhagat, 2015) combined data on land use/land cover (LULC), slope, soil depth, erosion, moisture, water holding capacity, texture, and availability of nutrient to study the land suitability for agriculture in hilly zones. A multidisciplinary study by Cai et al. (2011) compared sixteen soil property metrics related to productivity, slope, soil temperature regime, and moisture index, using the Soil Rating for Plant Growth Index (SRPG) developed by the US Department of Agriculture. The same approach was applied by Li et al. (2017) for an indicator of agricultural suitability. A number of indicators (slope, soil erosion, soil organic carbon, texture, pH, cation exchange capacity, soil depth, and drainage) were used in areas that had previously been excluded from LULC types, such as water bodies, protected areas, and human settlements. In the work of (Gopalakrishnan et al., 2011) crop sustainability concerns and economic considerations were incorporated into the identification of ML, i.e. soil health criteria (eroding soil, flooding frequently, poor drainage, steep slopes, and low productivity) were used to identify ML. Land use (such as idle and fallow land) and environmental degradation criteria (contaminated water resources, contaminated land, and water-constrained areas) were used to identify ML.

1.2. Distribution of marginal lands worldwide

Currently, salinity and sodicity harm 1,030 million hectares (Mha), with salinity affecting 412 Mha and sodicity affecting 618 Mha by sodicity (Qureshi, 2017).

Salinity impacts 76 million acres, with Asia having the largest concentration (53 million ha) (Dregne et al.,1991; Wicke et al., 2011). Of the total 76 Mha, 43 Mha are on irrigated areas in (semi-)arid parts of the world, with the remaining 33 Mha in non-irrigated lands. Despite the United Nations' forecast that the global population will reach 9.7 billion in 2050, scientists are concerned that industrial agriculture might not be able to keep up with food demand (UN, 2016). Global food demand is expected to grow 1.1% per year between 2005–2007 and 2050, which implies a 56% increase over this period (Alexandratos, 2012; McKenzie and Williams, 2015;). It is estimated that global food production in 2050 will need to be approximately 60% higher than in 2005-2007. This is in order to match the yearly growth in global food demand of 1.1% (Alexandratos et al., 2012). A 10% increase in cropped area would be appropriate with an increase in crop yields of 1.2% to 1.3% per year (Fischer et al., 2014). According to the study, marginal areas comprise 15 percent of agricultural lands worldwide and 21 percent of global land resources. There is no approach for identifying marginal land that is now commonly recognized. The approaches that are now used to assess marginal lands are primarily qualitative, only partially quanti-

Table 1
Salt-affected soils in drylands of different continents. Source: (FAO, 2015)

Continents	Sodic soils	Saline soils	Total (mln/ha)
Australia	340	17.6	357.6
Mexica/Central America	–	2	2
North America	9.6	6.2	15.8
South America	59.8	69.5	129.3
Southeast Asia	–	20	20
North and Central Asia	120.2	91.5	211.7
South Asia	1.8	82.3	84.1
Africa	86.7	122.9	209.6
World total	**618**	**412**	**1030**

tative, and, in some cases, very arbitrary (Csikós and Tóth, 2023; Kang et al., 2013). For instance, the number of marginal lands on a worldwide scale varies between research, varies from 1 million to 1 billion ha (The Worldwatch Institute, 2006), 385–472 million ha, and 1.3 billion ha (Campbell et al., 2008), or 36% of agricultural lands (Wood et al., 2000).

Most of the rural population in developing nations lives in these areas, which account for roughly one-third of the world's rural population. They conclude that policies for marginal areas should also integrate data generation and knowledge sharing. They suggest that land tenure reform may be needed to ensure more secure and equitable land access and property rights for farmers living in marginal areas (Ahmadzai et al., 2021). These salt-affected regions must be converted into fertile lands in order to enhance the livelihoods of rural pastoral populations. Afforestation has the capacity to re-vegetate salty soils, bringing economic advantages to pastoral people and decreasing high water table conditions through bio-drainage (Khamzina et al., 2008).

1.3. Economic, technical and environmental aspect of marginal lands

Economic, technical, and environmental impacts of biomass on salt-affected soils assessments were carried out worldwide by researchers and from one another. In an article by Birka Wicke et al., (2011) they examine the biomass production potential of salt-affected soils and conclude that increasing biomass production on these soils will significantly contribute to global and local (bio-)energy supply (Wicke et al., 2011). There are many additional benefits of biosaline forestry, including the improvement of soils, the generation of income from unused land, and the sequestration of carbon in soils (Wicke et al., 2011).

In case of United Arab Emirates UAE experience and scientists argued that Food security, poverty reduction, resiliency to climate change, and ecosystem health will all be improved by improving the sustainable use of marginal lands and water resources (Senior Scientist – Irrigation and Water Management, International Center for Biosaline Agriculture (ICBA), P.O. Box 14660, Dubai, UAE and Qureshi, 2017). Plant resources dedicated to salinity control and remediation, such as native and introduced halophytes and salt-tolerant plants, can play a significant role in the economic development of salt-affected dry regions. Desert and semi-desert areas of the region can benefit from the agroforestry concept by solving drainage problems on the farm and creating favorable environmental conditions (Qureshi, 2017).

In the view of Dr. Kristina Toderich that countries around the Aral Sea and the Caspian Sea struggle to produce enough food and animal feed to sustain their rapidly expanding populations because of a lack of fresh water. The field trials were conducted in the agropastoral sandy desert ecosystems of Central Kyzylkum (Uzbekistan) where hydrothermal saline water was used for irrigation with salt-tolerant crops. More than 53 varieties of Sorghum *(Sorghum bicolor)* and 11 varities of Pearl millet *(Pennisetum glaucum)* in various agro-ecological zones of each three countires (Agriculture for Marginal Lands in Central Asia, 2015). In the Central Asia (CA) area, the total losses and expenses related to desertification and land degradation have been assessed at $2.5 billion. The best solution of using of salt tolerant Sorghium and Pearl millet in marginal and salt-affected lands to improve biodiversity, soil fertility and water table accepted. In addition, by using unused agricultural lands to improve rural livelihood which are located around them.

Policies related to climate change are evaluated using marginal abatement costs (MAC) (Jiang et al., 2019). To that purpose, the process of innovation and technology advancement for marginal agricultural lands must be collaborative and demand-driven, encouraging and building on farmer inventions tailored to local conditions. Initiatives aimed at politicians, researchers, and agribusinesses must be coordinated with capacity-building activities to rebuild the knowledge base in marginalized and indigenous communities.

2. Methodology

As part of this step, we collected publications related to marginal lands between 1979 and 2022. Due to its lack of bibliometric data and low data quality, Google Scholar was dropped as the preferred database (Mongeon and Paul-Hus, 2016). Despite Web of Science (WOS) being a high-quality database, the research by Mongeon (Mongeon and Paul-Hus, 2016) and our practice together show that Scopus has a broader database coverage than WOS. Consequently, Scopus was used to find relevant research publications in this study. According to the objective of the research, three subject areas were selected from the Scopus database for the time period 1979-2022 and exported them to a CSV file. The boolean commands were as follows: (ALL (Environmental sciences) OR ALL (Agricultural and Biological Sciences) OR ALL (Earth and Planetary Sciences) AND PUBYEAR > 1979 AND PUBYEAR < 2022) (Li et al., 2022). Using the ALL search parameter in Scopus, it can include all the fields you want for your search, including the title, abstract, keywords, affiliation, funding information, reference information, and conference information (Li et al., 2022). Total obtained number of papers by subject areas: 1. Environmental Sciences – 702 papers 2. Agricultural and Biological Sciences – 601 papers 3. Earth and Planetary Sciences – 207

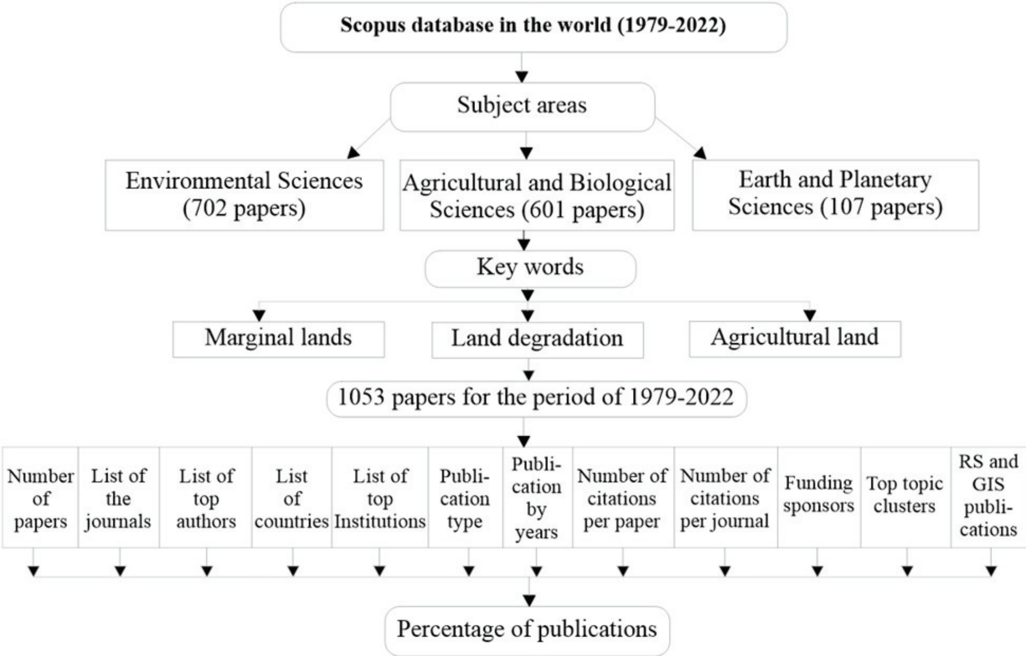

Fig. 1. Methodology flowchart for the research

papers. All publications were analyzed and reviewed using Marginal lands, Land degradation and Agricultural land as the keywords. Then, a database was categorized including the year of publication, journal names, authors' names, countries, the type of publication, the number of citations per paper, the number of citations per journal, and the percentage of publications by topic cluster name. In the end, the role of RS and GIS in marginal land issues was analyzed worldwide. In Fig. 1, you can see a flowchart of the research methodology chosen for this study.

3. Results

3.1. Published papers on marginal lands

The number of published papers on a particular issue shows the importance of that issue around the world. It has been reported that in the period 1979 to 2022, 1053 papers have been authored on marginal land issues. Fig. 2 shows that the number of publications on a given topic issue is increasing as an ascending year by year. The total number of publications from 1979 to 2007 was 157 and it made up only 15% of the total number of publications. All these years, the publication variation was around 2 up to 16 papers annually. As an example, in 1989 and 2007 years 16 papers were published, 1993 and 2005 years 10 papers were published respectively. At the beginning of 2018 and so far in 2014, the number of published works were significantly increased by 256 papers, with 24%. At the beginning of the last decade, the number of annual publications increased dramatically from 74 to 105 papers. In 2021, there were 105 papers published on the topic, which represents 10% of the total. From 2015 to the present, the total number of papers published is 640. The number of publications in the last eight years represents more than half of the entire amount of documents, 60%.

3.2. Journals on marginal lands

The publishing of research papers in top journals is essential to the publication process. Scopus-based 1053 papers on marginal lands, land degradation, and agricultural land issues were published in 154 journals. As can be seen in Table 2, I have selected 40 journals that have at least 5 papers published. The 524 papers in the selected journals are accounted for by 66% in the selected journals. This covers over half of the total quantity of publications. The first ten journals published papers are at least over the 15 number of publications. Top ten journals are Global change Biology (GcB) Bioenergy, Land Use Policy, Institute of Physics (IoP) Conference Series Earth and Environmental Science, Biomass and Bioenergy, Science of the Total Environment, Land Degradation and Development, Bioenergy Research, Journal of Environmental Management, Sustainability, Agroforestry Systems. The remaining 106 journals published 266 research articles, which takes 34%.

3.3. Top authors on marginal lands in the world

Researchers play a vital role in the development of a particular area of research in any part of the world. There have been 3698 different authors who have contributed to publishing 1053 papers on marginal lands issues in the world scope since 1979. Almost 12% of research papers were written by single authors, while the rest of the papers were published by two or more authors. More than one hundred authors Bush, M.B., Shortall. O.K., Borras Jr, S.M., Gade, D.W., Barbier, E.B., Blanco-Canqui, H., and other researchers published their papers as single authors. In the present review work, we selected the first 18 top authors which published at least 6 and more papers which are given in Fig. 3. The most productive researchers of the present work are leading from Italian Cosentino, S.L., Scordia, D., Testa, G., and Monti, A.,

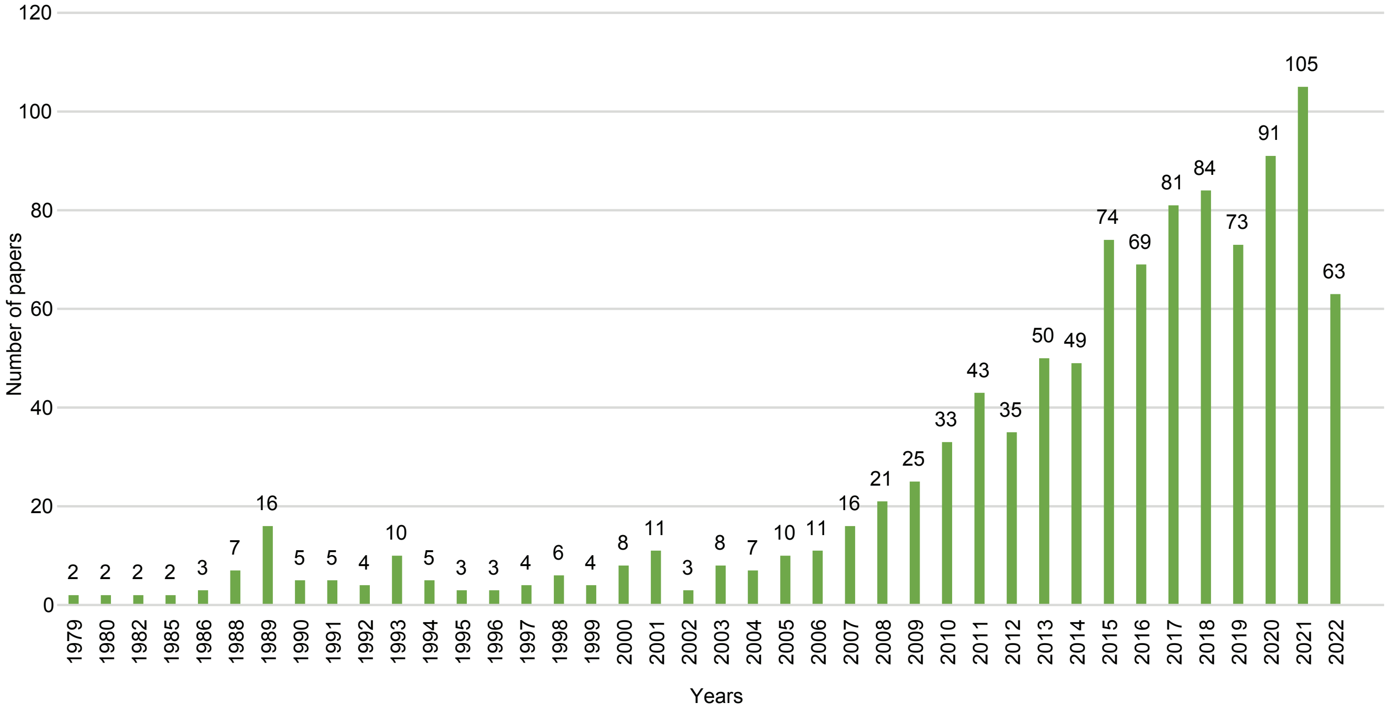

Fig. 2. Number of papers on marginal lands by the year of publication in the world

with the corresponding 19, 18, 14, and 13 papers respectively. All of Cosentino's publications are linked to 10 co-authors, and the total number of co-author links through these co-authors is 59. In the case of Scordia direct co-authorship is the same as the Cosentino's but the total link strength is 56 co-authorships. The Testa, G, and Monti, A's direct links with the co-authors are 8 and 6, additionally, their total link strengths are 48 and 18.

Uzbek scientists worked with international researchers as co-authors in the 2009 and 2019 years. Including Boboev H., Djanibekov U., and Bekchanov M., who worked with Lamers

Table 2
List of the journals on marginal lands in the world

Title of journal	Number	Title of journal	Number
Gcb Bioenergy	54	Catena	8
Land Use Policy	45	Energy Policy	8
Iop Conference Series Earth and Environmental Science	38	Soil Science Society of America Journal	8
Biomass and Bioenergy	34	Agricultural Systems	7
Science of the Total Environment	26	Ecological Applications	7
Land Degradation and Development	25	Ecological Economics	7
Bioenergy Research	23	Climatic Change	6
Journal of Environmental Management	22	Environmental Science and Technology	6
Sustainability	20	Journal of Applied Ecology	6
Agroforestry Systems	15	Land Economics	6
Agriculture Ecosystems and Environment	14	Water Switzerland	6
Industrial Crops and Products	14	Applied Energy	5
Agronomy	10	Biomass	5
Geografisk Tidsskrift Danish Journal of Geography	10	Ecological Engineering	5
Italian Journal of Agronomy	10	Environmental Modelling and Software	5
Environmental Management	9	Environmental Monitoring and Assessment	5
Environmental Research Letters	9	Forest Ecology and Management	5
Forests	9	Landscape and Urban Planning	5
Journal of Arid Environments	9	Landscape Ecology	5
Agricultural Water Management	8	New Forests	5

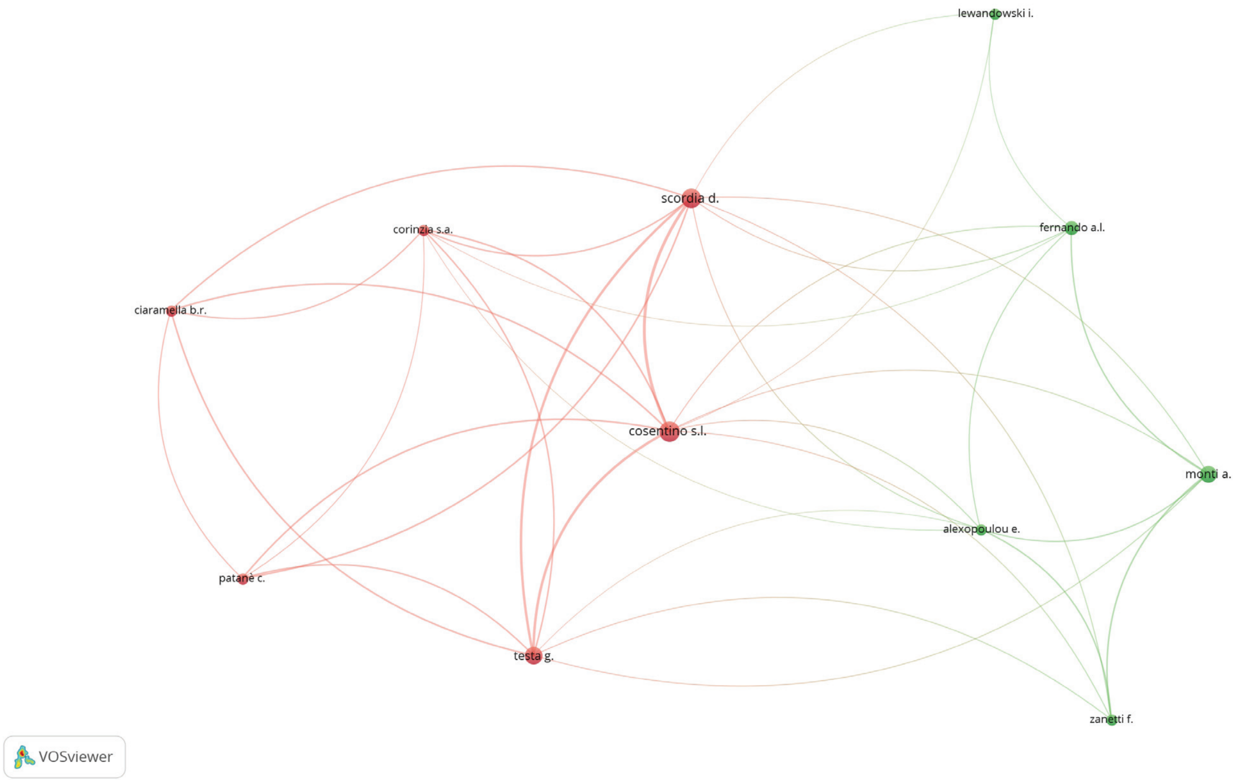

Fig. 3. The top authors and co-authorships on marginal lands in the world

J.P.A., Toderich K. in 2019. In 2009, Radjabov T., Bekchanov B.B., Aralova D.B., worked with Toderich K.N., Shuyskaya E.V., Ismail S., Gismatullina L.G.

3.4. Top published countries on marginal lands

The number of countries that participated in the research activities on a specific topic shows the degree of internationalization of the region. A total of 109 countries have worked together on the marginal land issue in the world between 1979-2022. We have selected the top 19 countries that participated in the publishing of at least 20 and more publications in Fig. 4. Among the top countries by number of publications, the United States ranked 17%, China 7%, Italy 7%, Germany 5%, United Kingdom 5%, India 4%, Indonesia 4% and Spain 3% each have 262, 111, 110, 85, 82, 66, 61 and 54 papers respectively. European countries worked more with the given topic issue and published 671 papers with 43% in the world. Asian and American countries are 405, 348 with, 26% and 22% respectively. The last one is the African countries published 65 papers with 4%. Among the top publication countries, Uzbekistan and Uzbek scientists published two papers on marginal land, accounting for 0.1% of the total number of papers published.

3.5. Top institutions on marginal lands

The ranking of institutions is mostly based on the quality of the papers published by the researchers of that institution on the world scale. One hundred sixty different institutions worked in cooperation to publish 1053 papers on marginal lands in the world from 1979 to 2022. In this research, we selected 24 Institutions of higher education with the best performance on the marginal lands that published at least 10 papers in Fig. 5. Selected Institutions published 407 papers on the given topic and it belongs to 37% of the global scale. The most effective Institution in the world scale on the given topic is the Chinese Academy of Sciences – Yangling, China with a 5% share, where 48 papers were published. The next highest ranked institutions were Wageningen University & Research – Wageningen, Netherlands with 28 articles, and the University of Illinois Urbana-Champaign – Urbana, United States with 27 articles, and, 3% on a global scale respectively. A total of eight institutions, including The Michigan State University – East Lansing, United States, Università Degli Studi di Catania – Catania, Italy, Consiglio Nazionale Delle Ricerche – Catania, Italy, Sveriges lantbruks Universitet – Uppsala, Sweden, Purdue University – West Lafayette, United States, Alma Mater Studiorum Università di Bologna – Bologna, Italy, Iowa State University – Ames, United States, and the University of Wisconsin-Madison – Madison, United States each published 2% of a total number of articles. The other Institutions published between three and nine papers on the given topic, with 63 percent.

3.6. Publication type on marginal lands

This review work collected different types of publications where researchers can show their results. Published papers on marginal lands in the world for the given topic between the given 1979–2022 years period are presented in 6 different types of publications in Fig. 6. We have selected publication types based on the number of publications, as shown

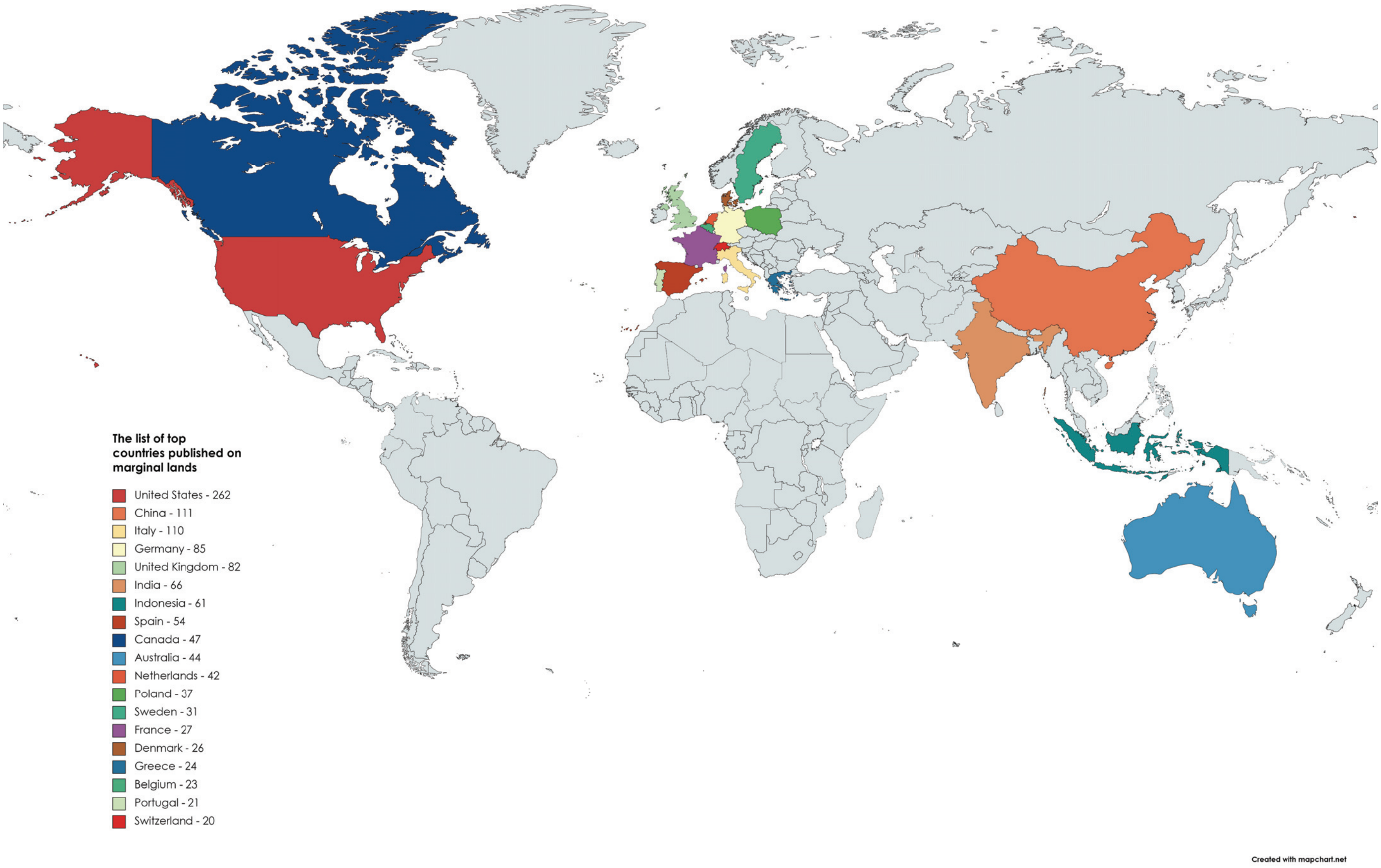

Fig. 4. Graphical distribution of top countries on marginal land issue in the world

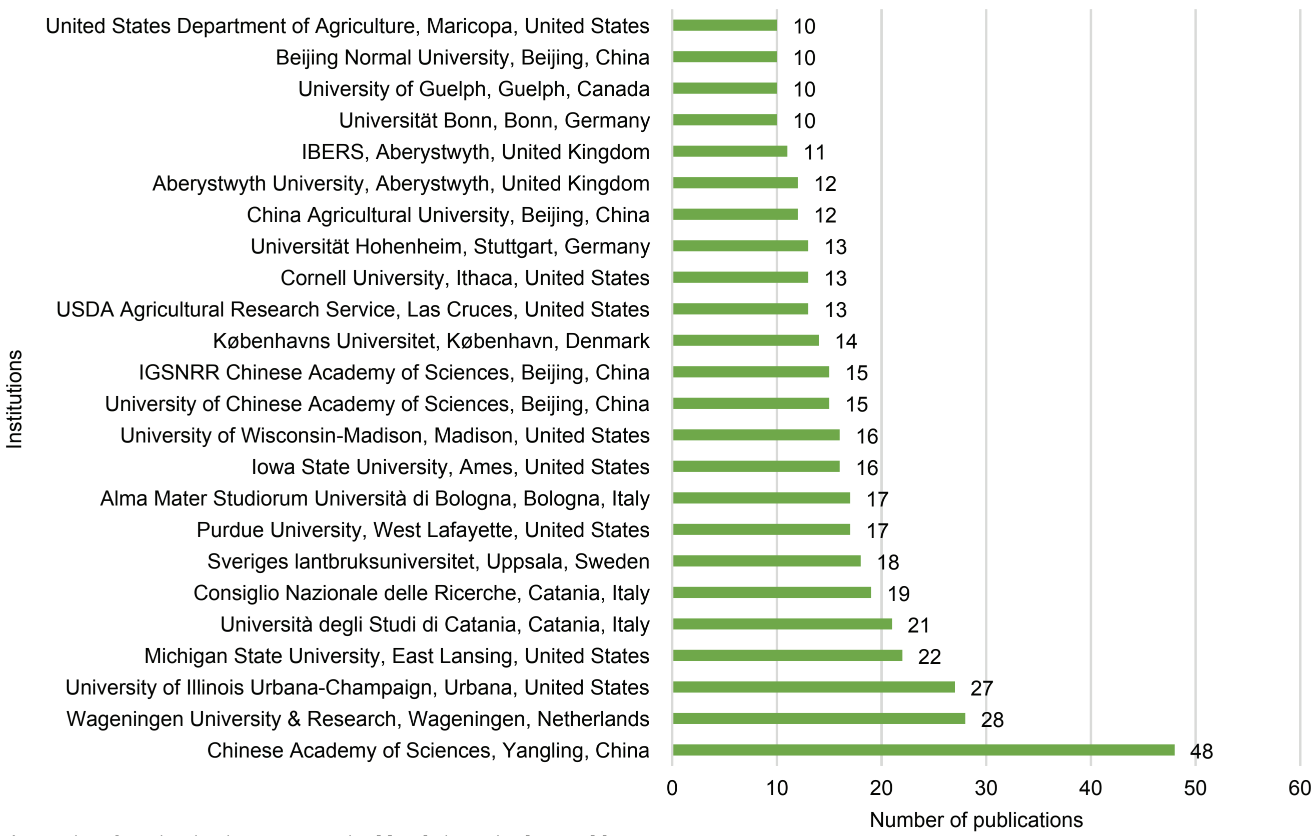

Fig. 5. List of top institutions on marginal lands issue in the world

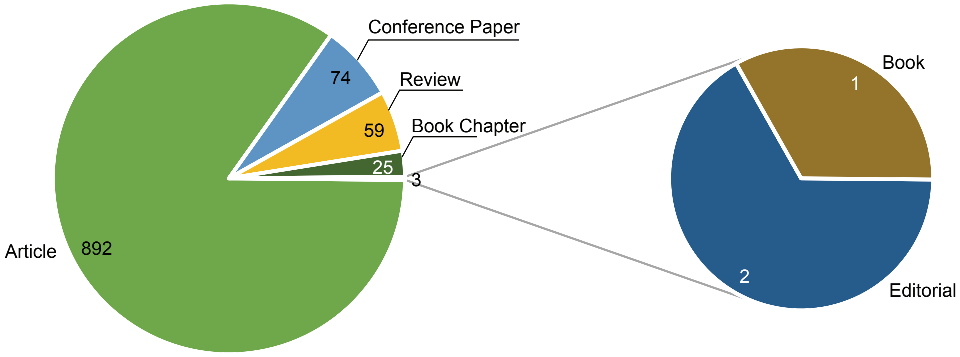

Fig. 6. List of publication type on marginal lands issue in the world

in Figure 6. Among the other variety of publications, research articles were published in 892 papers on marginal land issues, accounting for 85% of overall types. In the next step, 7% of the total published papers belong to the Conference paper. In the Review and Book chapter segment researchers published 59 and 22 papers with a 5,6 and 2,4% share respectively. The last types of publications that we selected are Editorials and Books where 2 and 1 papers were respectively published during the given period.

3.7. The number of publications by years

In the previous pie chart, we have shown the types of publications in this research work. This analyzed line graph shows us the number of publications on the given topic by year in Fig. 7. Articles are the most published type in this review work. From 1979 to 1992 years there were not published any other types of documents except the Article type. During the given period 1053 publications were published and the higher-ranked year is 2017 with 78 papers. Conference papers were published 35 papers up to 2019, but in 2020 and 2021 years the number of publications increased to 39 papers with 52% simultaneously. In the Review work 59 papers in total, the more published year in 2020 with 10 papers released and the number of publications on the given topic started raising from 2011. But in the last two years, the number of publications decreased than 2020. The next one is the book chapter published 25 documents. The higher-ranked year is 2015 with 7 papers. This type of research work started at the beginning of the previous decade. Unfortunately, in the last three years, there is no published marginal land issue-related papers. Editorial and Book types of publications are not actively published in the given topic issue. Two types of publications cover just 3 papers during the whole given years. In a conclusion, just article type of documents was published within the given period without any skipping years. The rest of the other types fluctuated.

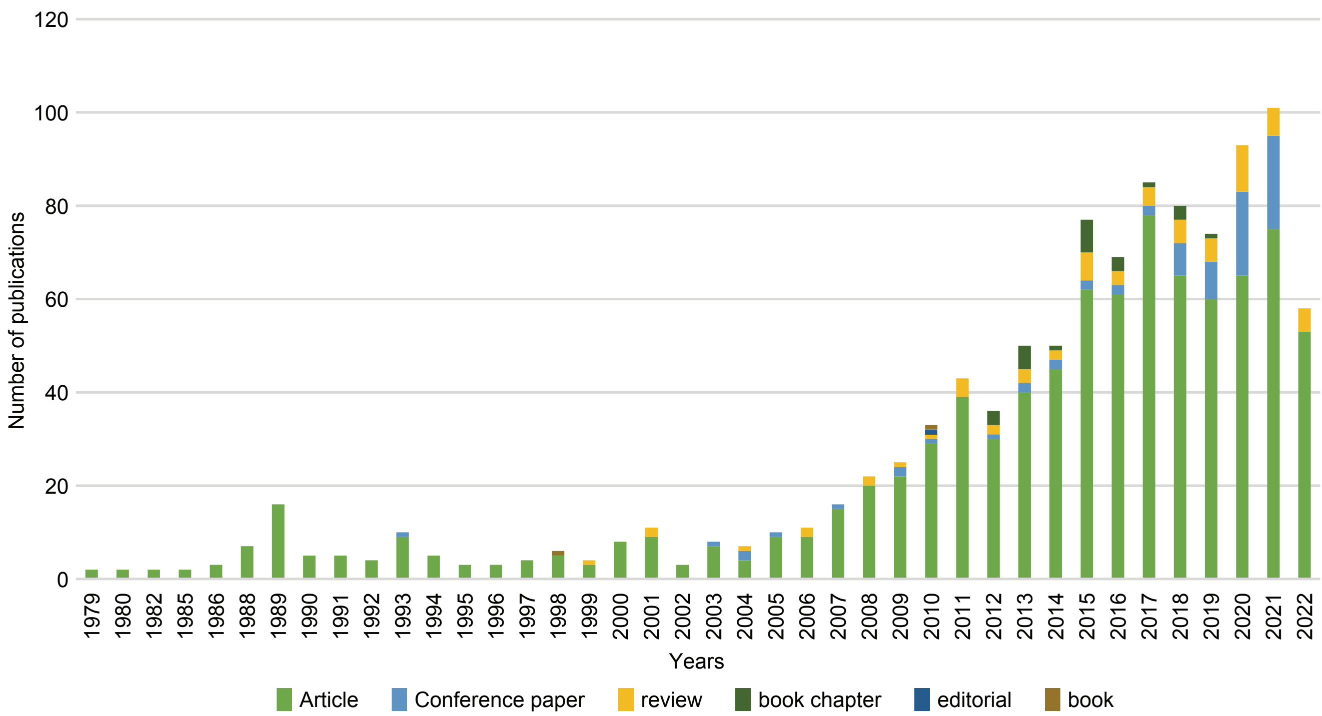

Fig. 7. List of publication by years on marginal lands issue in the world

3.8. Top cited papers by authors & subjects on marginal lands in the world

Based on the number of citations of publications shows the quality and novelty of the research papers. Ten of the most cited papers on marginal lands are selected and shown in Table 3. A total of 26223 citations were given to 1053 publications on marginal lands for the Globe for the given period. The most cited scientific paper is released "Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response" in the 2000 year by authors D. MacDonald, J.R. Crabtree, G. Wiesinger, T. Dax, N. Stamou, P. Fleury, J. Gutierrez Lazpita, A. Gibon with 1439 citations in the 22 years. As well as among the subjects the most cited one was "Environmental Science" with 986 citations acquired for the given paper and this type of subject area was the most cited in all selected papers. Additionally, among the cited countries China stood first with 397 citations to the "Impact of urbanization on cultivated land changes in China" paper and also stood first as the most cited country in seven of ten selected papers. Over 17% of the total citations were given to 10 papers from Table 3, and all selected documents type belonged to the article.

Table 3
List of top cited publications by authors and subjects on marginal lands in the world.

Name of article	Subject area	Number of citations	Country	Number of citations
Agricultural abandonment in mountain areas of Europe: Environmental consequences and policy response	Environmental Science	986	Italy	320
	Agricultural and Biological Sciences	697	Spain	320
	Social Sciences	485	Germany	169
	Earth and Planetary Sciences	219	Switzerland	125
	Energy	85	United Kingdom	125
	Engineering	59	China	121
	Computer Science	50	France	117
The role of agri-environment schemes in conservation and environmental management	Environmental Science	415	Germany	136
	Agricultural and Biological Sciences	350	United Kingdom	124
	Social Sciences	145	United States	56
Rewilding Abandoned Landscapes in Europe	Environmental Science	295	Spain	92
	Agricultural and Biological Sciences	201	Germany	73
	Social Sciences	114	United Kingdom	65
	Earth and Planetary Sciences	49	United States	52
Impact of urbanization on cultivated land changes in China	Environmental Science	294	China	397
	Social Sciences	177	United States	50
	Agricultural and Biological Sciences	106		
Impact of China's Grain for Green Project on the landscape of vulnerable arid and semi-arid agricultural regions: A case study in northern Shaanxi Province	Environmental Science	246	China	319
	Social Sciences	165		
	Agricultural and Biological Sciences	81		
Patterns and drivers of post-socialist farmland abandonment in Western Ukraine	Environmental Science	228	China	95
	Social Sciences	153	Germany	76
	Agricultural and Biological Sciences	125	United States	59
	Earth and Planetary Sciences	93		
Land availability for biofuel production	Environmental Science	180	United States	146
	Energy	134		
	Agricultural and Biological Sciences	124		
Determinants of agricultural land abandonment in post-Soviet European Russia	Environmental Science	197	China	86
	Social Sciences	134	Russian Federation	61
	Agricultural and Biological Sciences	115	Germany	60
	Earth and Planetary Sciences	82	United States	56
Policy reform and agricultural land abandonment in the EU	Environmental Science	214	China	51
	Social Sciences	130	Italy	51
	Agricultural and Biological Sciences	127		
Grain-for-green policy and its impacts on grain supply in West China	Environmental Science	181	China	239
	Agricultural and Biological Sciences	94	United States	53
	Social Sciences	91		

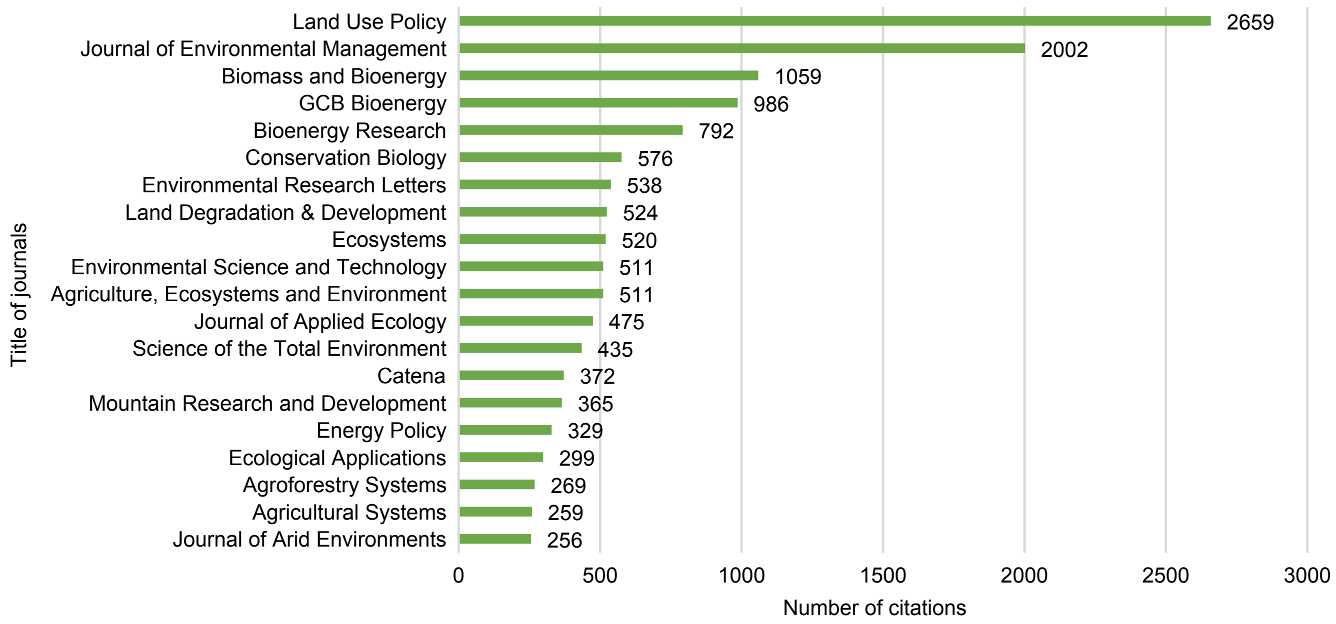

Fig. 8. List of top cited journals on marginal lands in the world

3.9. Top cited journals on marginal lands

A total of 1053 papers were published in the 150 journals on the marginal lands issue around the world in the given period. The top cited 20 journals selected and shown in Fig. 8. Almost over half of the citations, 52% were given to papers published in these 20 journals. Land Use Policy journal has given 2659 citations during the whole period leading with 10 % of the total number of citations and leading the top cited journals list. Next two most cited Journal of Environmental Management and Biomass and Bioenergy journals are leading the top cited list of journals on marginal land issue around the world with 2002 and 1059 citations with 7.6 % and 4% respectively.

3.10. Funding sponsors on marginal lands in the worldwide

This part of the review work was considered to express the number of publications published regarding the marginal lands sponsored by funding sponsors in the world. The total number of funding sponsors establishments is 156 on marginal lands around the world and they released 693 different types of publications. Between the total number of funding sponsors, we selected below the top fourteen sponsors (Fig. 9), sponsored by at least 10 publications. The total number of publications of selected sponsors is 329 documents and it belongs to 47% of the total number of publications. One of the most active "National Natural Science Foundation of China" sponsored 51 publica-

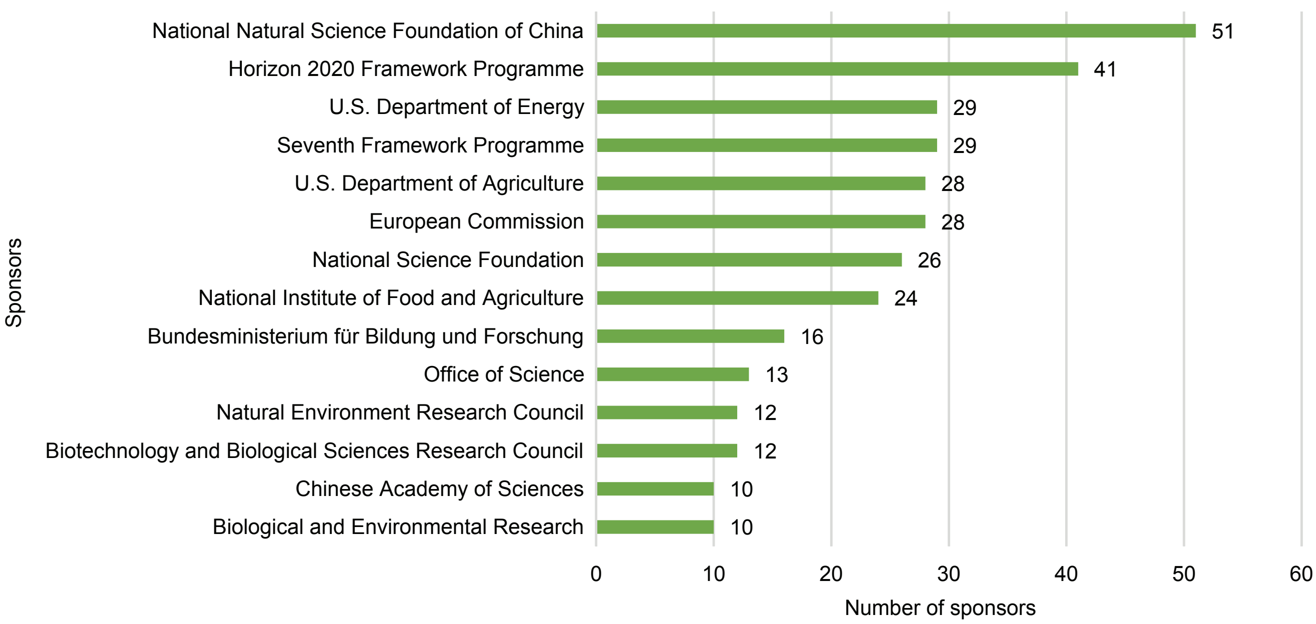

Fig. 9. List of funding sponsors on marginal lands in the world.

tions during this period, with a 7% share. Next on "Horizon 2020 Framework Programme" was recorded with a one percent difference with a share of 6% and 41 publications. "National Science Foundation, European Commission, U.S. Department of Agriculture, Seventh Framework Programme, U.S. Department of Energy" sponsored with a share of 4% respectively. Last but not least, all other sponsors were varied between 3% to 1% respectively.

3.11. Publications by the topic cluster name on land degradation

There are different topic cluster names available for the subject categories in the Scopus database. In the review, we used 3177 author keywords in order to analyze the most appropriate clusters. In Fig. 10, we see that the vast majority of papers on marginal lands in the world fall under 4 topic cluster names. Marginal lands, Land degradation, abandoned land topic cluster name covers 13% of total publications. In contrast, Land use, Agriculture, Agroforestry, Soil fertility, Sustainability, Climate change 8%, GIS, Remote sensing, Spatial analysis 2% and Biofuel, Bioenergy crop, Biomass cluster covers 5% of total publications.

3.11. Role of Remote Sensing and GIS technologies on marginal lands

In the last decades, advanced technologies were started using in science by researchers. For example, GIS and RS spatial technologies are widely used in almost all spheres of science. The analysis of the marginal lands in the world shows us that 5% of total publications are belonging to the GIS and RS technologies, shown in Fig. 11. In order to release publications 29 journals were selected around the world. Most Rs and GIS technologies-related papers were published by US researchers. From 1979 till the end of the first decade of the present century published only 5 papers. The main reason for that was that globalization wasn't actively working in the world. However, the beginning of the last decade and other years recorded one of the peak points of the given period with 8 papers 2011, 2013 2015 respectively. During the given last decade total number of pub-

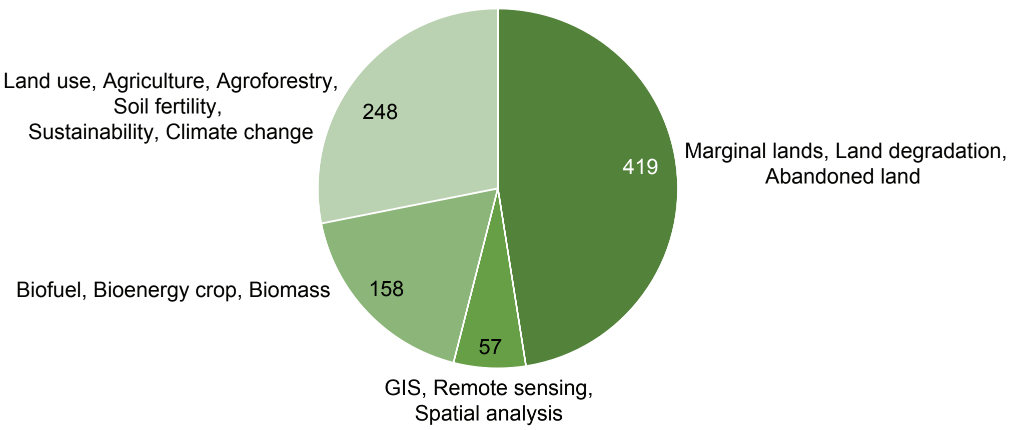

Fig. 10. Top topic cluster name on marginal lands in the world

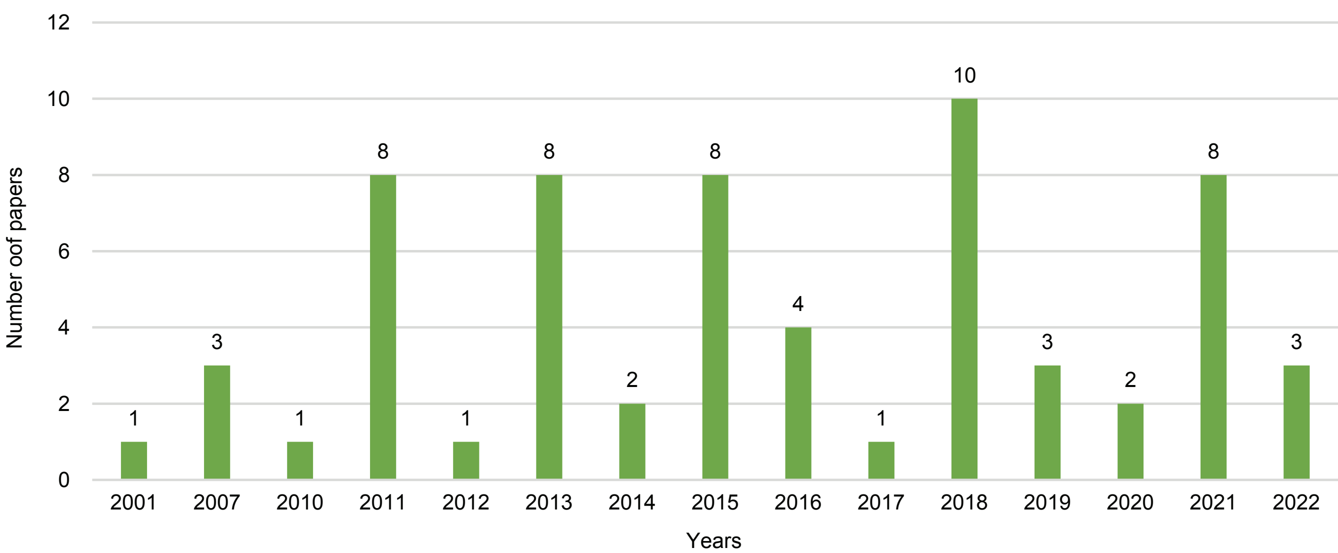

Fig 11. Remote sensing and GIS based papers on marginal lands in the world

lications was 47 papers on the topic of RS and GIS with 75% of the total number of published RS and GIS technologies papers. The most productive year of the last decade is the 2018 with 10 papers. In the last two years on the given topic related to RS and GIS technologies papers published 11 with 8 papers in 2021 and 3 papers in 2022.

4. Conclusions

In this analysis, various types of scientific papers written on marginal lands from 1979 to 2022 were retrieved from the Scopus database in English. Our analytical work shows that the word “marginal land” itself is considered a new word in science, and we are sure that its meaning changes depending on the purposes, time, and place of its use. The main highlights are the growing interest in marginal lands and their potential for sustainable development. Based on the review of papers on marginal lands, it appears that marginal lands have the potential to contribute to sustainable development by producing biomass, sequestering carbon, and conserving biodiversity. To manage and utilize marginal lands effectively, we need to understand their full potential and develop effective strategies. Furthermore, remote sensing and GIS technologies enable us to monitor changes in marginal lands over time. They can help evaluate the ecological and socioeconomic effects of different management practices on marginal land conditions, as well as identify patterns and trends in land use and land cover changes. The review work shows that most developed countries were researching marginal lands. Because these countries have a high economic potential to support research to formulate capacity-building, increase awareness among the people and use advanced technologies in the pilot areas for instance, China and the United States. However, developing countries have several problems and constraints to research marginal lands. Because taking into account that almost all the marginal lands are situated in remote areas and have limited access to infrastructure it can make it difficult to develop and implement management practices that are appropriate for local conditions. It demands some investment by the government. In addition, one of the main reasons for the lack of knowledge and understanding of the potential benefits and challenges of using marginal lands and the lack of the technical and financial resources needed to effectively utilize marginal lands. In order to advance research and development concerning marginal lands, it is imperative that further investigation be conducted on the considerable potential of these lands for bioenergy production, carbon sequestration, and biodiversity conservation practices. The primary objective of this study is to ascertain the most appropriate and enduring management strategies for various categories of marginal lands, while also evaluating their effects on the environment and socio-economic factors. Additionally, initiatives such as training programs, knowledge platforms, and networks can be used to strengthen capacity development and knowledge sharing on marginal lands, enabling the development of technical and institutional capacities for sustainable management and utilization.

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Competing interests

The authors declare no competing interests.

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