The 30th

Annual International Conference of ISDRS on Sustainable Development Research

Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood

PROCEEDINGS

June 10-14, 2024 | Kathmandu, Nepal

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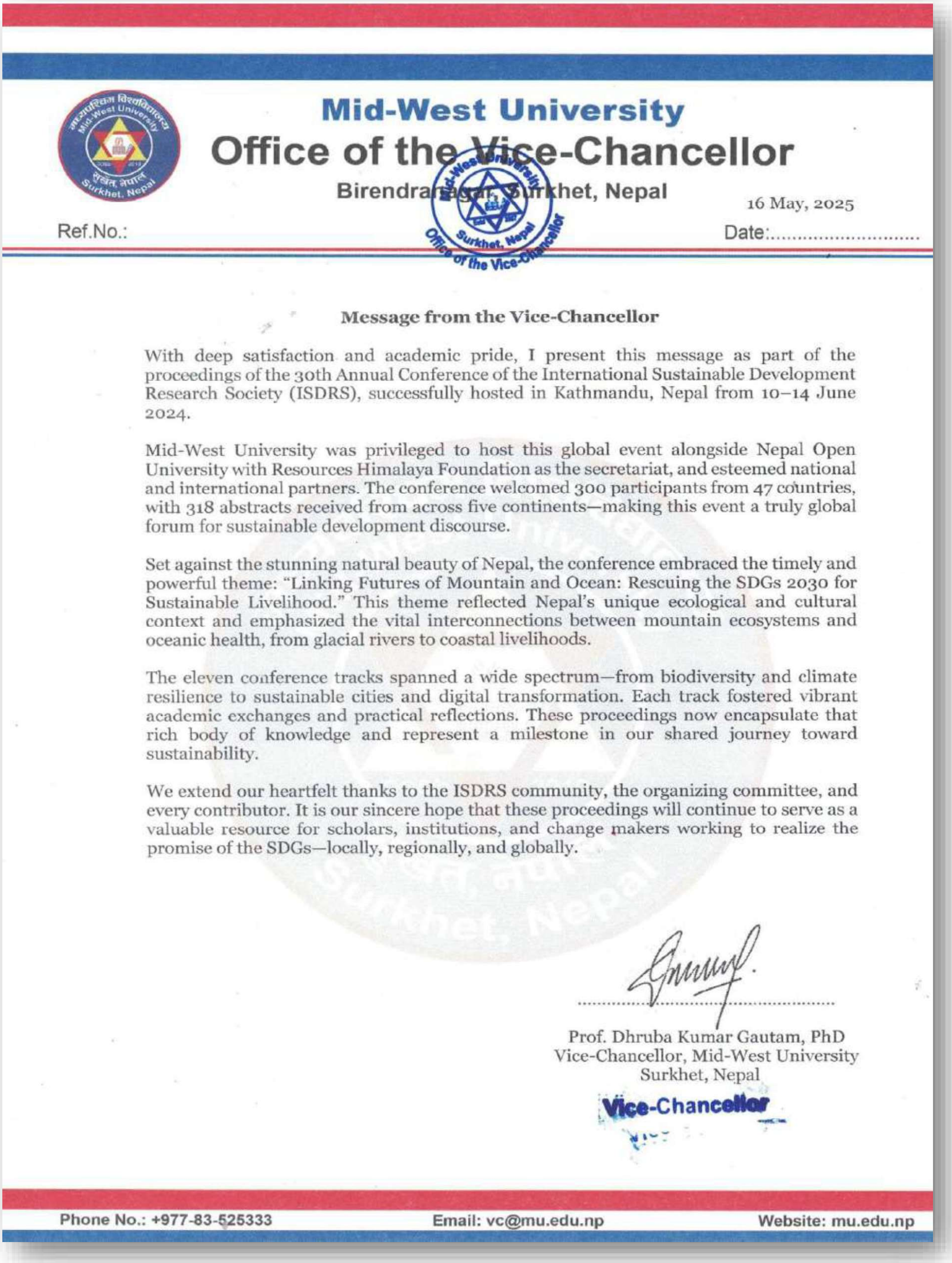

Mid-West University
Office of the Vice-Chancellor
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Message from the Vice-Chancellor

With deep satisfaction and academic pride, I present this message as part of the proceedings of the 30th Annual Conference of the International Sustainable Development Research Society (ISDRS), successfully hosted in Kathmandu, Nepal from 10–14 June 2024.

Mid-West University was privileged to host this global event alongside Nepal Open University with Resources Himalaya Foundation as the secretariat, and esteemed national and international partners. The conference welcomed 300 participants from 47 countries, with 318 abstracts received from across five continents—making this event a truly global forum for sustainable development discourse.

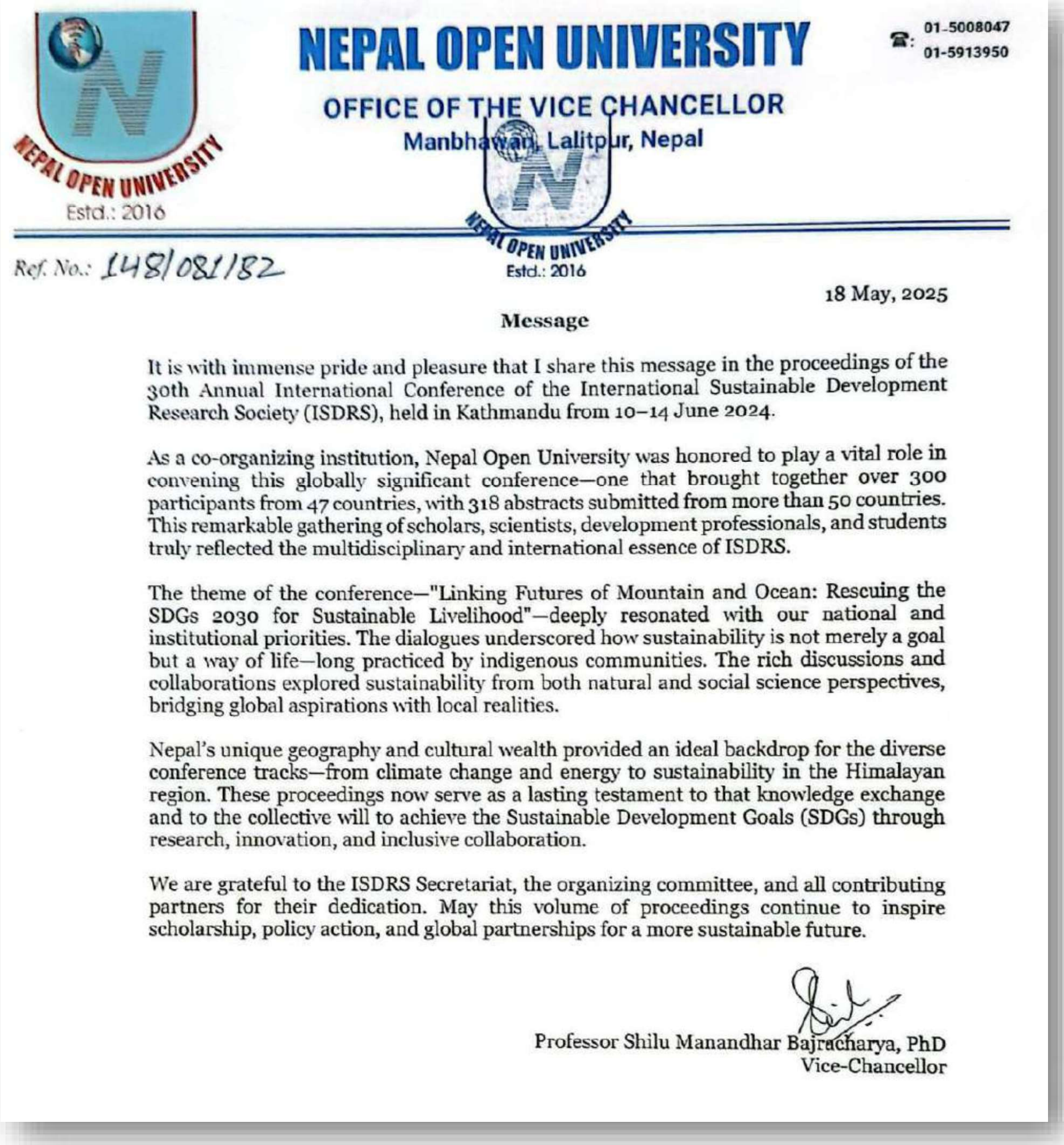
Set against the stunning natural beauty of Nepal, the conference embraced the timely and powerful theme: "Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood." This theme reflected Nepal's unique ecological and cultural context and emphasized the vital interconnections between mountain ecosystems and oceanic health, from glacial rivers to coastal livelihoods.

The eleven conference tracks spanned a wide spectrum—from biodiversity and climate resilience to sustainable cities and digital transformation. Each track fostered vibrant academic exchanges and practical reflections. These proceedings now encapsulate that rich body of knowledge and represent a milestone in our shared journey toward sustainability.

We extend our heartfelt thanks to the ISDRS community, the organizing committee, and every contributor. It is our sincere hope that these proceedings will continue to serve as a valuable resource for scholars, institutions, and change makers working to realize the promise of the SDGs—locally, regionally, and globally.

Prof. Dhruba Kumar Gautam, PhD
Vice-Chancellor, Mid-West University
Surkhet, Nepal

Vice-Chancellor



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Message

It is with immense pride and pleasure that I share this message in the proceedings of the 30th Annual International Conference of the International Sustainable Development Research Society (ISDRS), held in Kathmandu from 10–14 June 2024.

As a co-organizing institution, Nepal Open University was honored to play a vital role in convening this globally significant conference—one that brought together over 300 participants from 47 countries, with 318 abstracts submitted from more than 50 countries. This remarkable gathering of scholars, scientists, development professionals, and students truly reflected the multidisciplinary and international essence of ISDRS.

The theme of the conference—"Linking Futures of Mountain and Ocean: Rescuing the SDGs 2030 for Sustainable Livelihood"—deeply resonated with our national and institutional priorities. The dialogues underscored how sustainability is not merely a goal but a way of life—long practiced by indigenous communities. The rich discussions and collaborations explored sustainability from both natural and social science perspectives, bridging global aspirations with local realities.

Nepal's unique geography and cultural wealth provided an ideal backdrop for the diverse conference tracks—from climate change and energy to sustainability in the Himalayan region. These proceedings now serve as a lasting testament to that knowledge exchange and to the collective will to achieve the Sustainable Development Goals (SDGs) through research, innovation, and inclusive collaboration.

We are grateful to the ISDRS Secretariat, the organizing committee, and all contributing partners for their dedication. May this volume of proceedings continue to inspire scholarship, policy action, and global partnerships for a more sustainable future.

Professor Shilu Manandhar Bajracharya, PhD
Vice-Chancellor

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Preface and Acknowledgements

The International Sustainable Development Research Society (ISDRS) held its 30th annual international conference in Kathmandu, the capital of the Himalayan nation of Nepal. The conference marked a significant milestone in advancing the global sustainability agenda. Hosted in a hybrid format, the conference brought together over 250 participants from 47 countries, representing one of the most extensive international gatherings in the post-COVID-19 "new normal."

The conference was inaugurated by the Vice President of Nepal, while the Deputy Prime Minister and the Minister for Foreign Affairs participated in the valedictory session, underscoring the national significance of the event.

Nepal's new universities Mid-West University and Nepal Open University jointly hosted the conference. They established an inclusive academic platform by engaging five recently founded universities from across the country: Agriculture and Forestry University, Far-Western University, Madhesh University, Purbanchal University, and Rajarshi Janak University. This collaborative initiative laid the groundwork for stronger inter-university cooperation across Nepal.

In addition to the universities, the conference was supported by 12 key institutions, including the University Grants Commission (Nepal), the National Trust for Nature Conservation (Nepal), UNDP, and UNESCO. Serving as the conference secretariat, the Resources Himalaya Foundation played a central role in coordinating logistics and mobilizing resources.

The conference featured 220 research contributions across 10 thematic tracks, showcasing the interconnected and multifaceted nature of sustainable development. It highlighted the critical need for inter- and transdisciplinary collaboration, localized strategies, and inclusive approaches. Of particular significance was the strong participation of scholars from the Global South and women researchers, whose contributions emphasized the importance of addressing context-specific sustainability challenges and solutions.

The event called for the strengthening of research cultures in emerging academic institutions, improved science communication, and deeper engagement with issues of equity and planetary boundaries. These themes are especially relevant for Nepal—a Least Developed Country facing severe climate vulnerability. Melting Himalayan glaciers, rising frequency of wildfires, and increasingly erratic weather patterns are threatening livelihoods, particularly in rural farming communities. The timing of the conference was pivotal, as Nepal aspires to graduate to a developing nation status amidst these mounting sustainability challenges.

The conference served both as a challenge and an opportunity. It identified the urgent need to build robust platforms and mechanisms for collaboration among key actors in the Global South and emerging economies, reaffirming their crucial roles in achieving the Sustainable Development Goals (SDGs).

One of the key outcomes of the conference was the adoption of the Kathmandu Communiqué, which emphasized the importance of integrating the SDGs with planetary boundaries and understanding the socio-economic dimensions of sustainability—particularly equity, inclusivity, and the impacts of sustainability transitions on vulnerable populations.

We sincerely thank all partner organizations, volunteers, researchers, and scholars whose commitment and contributions were instrumental in making this conference a meaningful and memorable milestone in the global dialogue on sustainable development.

We extend special appreciation to the track reviewers, paper and poster presenters, and all participants, whose active engagement played a vital role in the conference's success.

Prof. Sjors Witjes, PhD
President
ISDRS 2024

Prof. Dinesh Bhuju, PhD
Convener
30th ISDRS Conference 2024 Kathmandu

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Statistical Variability of LCA Results Using Regionalized and Representative Inventory Data: The Case of Olive Production in Italy

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Abstract

Life Cycle Assessment (LCA) is one of the most adopted methods for assessing the potential environmental impacts associated with the life cycle of agri-food products and related agricultural practices. Despite this, there is a common consensus among scholars on the need for site-specific Life Cycle Inventories (LCIs) that should be as much as possible representative of the investigated agri-food system. In this regard, the Research Projects of National Interest (PRIN) 2017 "Promoting Agri-Food Sustainability: Development of an Italian LCI Database of Agri-Food Products (ILCIDAF)" aimed at developing Italian regionalized databases including representative LCIs for four agri-food products, to be used in LCA studies, i.e., cereal and pasta, wine, citrus and olive oil. The aim of this study is to analyse the statistical variability, among 19 Italian regions, in terms of Life Cycle Impact Assessment (LCIA) results that may occur using inventories that are representative of each region. Results show high variability among the 19 Italian regions in all the impact categories investigated. In particular, the coefficient of variability ranges from 43.87% in climate change to 49.75% in eutrophication (freshwater). The highest variability, in all the analysed impact categories, emerges for ferilizers and diesel production, and direct emission to air.

Introduction

Agri-food productions are responsible for high environmental impacts, accounting, globally, for onethird of anthropogenic greenhouse gas emissions, 70% of water use and 90% of deforestation. Agricultural activities also contribute to 70% and 50% of terrestrial and freshwater biodiversity loss as well as they cause land degradation (UNCCD, 2022). Furthermore, the World population is expected to reach 8.6 billion people in 2032, causing a yearly growing demand for food products for about 1.3% (OECD and FAO, 2023). This may result in further environmental issues mainly connected to agricultural practices implemented for food production.

Life Cycle Assessment (LCA) is considered the most suitable and adopted method for assessing the environmental impacts related to agricultural processes and food production (Notarnicola *et al.*, 2017). Indeed, LCA is a standardized method that allows the assessment of the potential environmental impacts associated with a process, product, or service throughout its whole life cycle, from raw material extraction and processing, through manufacturing, transport, use and end-of-life (Guinée, 2002). According to the ISO 14040:2006 standard (ISO, 2006), the LCA framework is characterized by four iterative phases, i.e., 1) Goal and scope definition; 2) Inventory analysis; 3) Impact assessment; and 4) Interpretation. With specific regard to the Life Cycle Inventory (LCI), various scholars highlighted the need to collect and use data that are as much as possible representative of the investigated system (Notarnicola *et al.* 2022; Frischknecht *et al.*, 2019). Indeed, the use of site-specific data would improve the representativeness and reliability of the LCA outcomes. This is particularly true for the agri-food sector, in which agricultural activities and food processing may strongly vary among different geographical contexts. Indeed, technological, biological, and environmental factors characterise each agri-food system and the related production processes (Liliane and Charles, 2020), thus requiring sitespecific and representative data for LCA practitioners. In this context, the Research Projects of National Interest (PRIN) 2017 "Promoting Agri-Food Sustainability: Development of an Italian LCI Database of Agri-Food Products (ILCIDAF)" had the scope of developing a database, to be used in LCA studies, including LCIs datasets representative and regionalized for the Italian context, and related to four agrifood products, i.e., cereal and pasta, wine, citrus and olive oil. The ILCIDAF database (ILCIDAF, 2024), which includes 924 datasets, has been developed using both primary sources directly collected through questionnaires and direct interviews submitted to agri-food companies and secondary data obtained through statistical databases, agricultural handbooks and scientific literature related to the Italian context.

Starting from the ILCIDAF database, this study aims to assess the potential environmental impacts related to agricultural practices implemented for olive production among 19 Italian regions – i.e., Abruzzo (ABR), Apulia (APU), Basilicata (BAS), Calabria (CAL), Campania (CAM), Emilia Romagna(EMR), Friuli Venezia Giulia (FVG), Lazio (LAZ), Liguria (LIG), Lombardy (LOM), Marche (MAR), Molise (MOL), Piedmont (PIE), Sardinia (SAR), Sicily (SIC), Tuscany (TUS), Trentino Alto Adige (TAA), Umbria (UMB) and Veneto (VEN) – through the application of the LCA method. In particular, the scope is to investigate the statistical variability, among these regions, in terms of Life Cycle Impact Assessment (LCIA) and to point out the importance of using inventories that are representative of specific regional contexts.

Literature Review

Various commercial and non-commercial LCA databases are available for practitioners involved in the analysis of agri-food systems. Some of these databases are specifically related to the agri-food sector, such as Word Food LCA Database (WFLDB) (Nemecek *et al.*, 2019), Agribalyse (Koch & Salou, 2020) or Agri-footprint (Blonk Consultants, 2014), while others include data related to multiple sectors, such as Ecoinvent (Frischknecht *et al.*, 2005). In addition, despite some LCA databases being proposed in order to cover a specific national context (e.G, Agrybalise for France), most of them include multigeographical boundaries, from World to national level, but none focus on a regional context.

The article proposed by Mondello *et al.* (2022) highlighted that Ecoinvent is mostly used as a standalone database or in combination with other databases in studies in which the agri-food sector and, in particular, the olive oil supply chain, are evaluated through the LCA method. Indeed, LCA practitioners commonly require the use of secondary data through dedicated databases, when foreground data are not available. Despite Ecoinvent being considered one of the most well-known and exhaustive databases, including more than 20,000 datasets related to various materials, energy sources and processes (Ecoinvent, 2024), it may lack geographical representativeness for data related to agri-food systems. Indeed, with specific regard to olive oil production in Italy, Notarnicola *et al.* (2022) pointed out that only one dataset is focused on the agricultural processes (i.e., olive production) related to this supply chain, including 70 data among inputs and outputs, of which only 4 are specifically related to Italian boundaries. In this context, the use of LCI datasets that are non-representative nor regionalized for a specific geographical context may lead to biases and uncertainty in the results obtained through the LCIA phase in LCA studies focused on olive or olive oil production as well as on the agri-food sector in general. Thus, the study here proposed has the scope of highlighting the need for inventory data that are able to capture the different factors affecting agricultural processes and related products among various geographical boundaries.

Methodology

In this section, the four methodological phases included in the LCA framework (ISO, 2006) are reported, describing its implementation in the investigated olive production systems in 19 Italian regions.

Goal and Scope Definition

The goal of this study is to assess the potential environmental impact related to olive production in 19 Italian regions. In particular, a hotspot analysis is performed in order to understand which inputs, outputs or processes are responsible for the highest environmental impacts among regions. Then, a statistical analysis is applied to LCIA results, to point out the grade of variability occurring between regions in terms of environmental impacts, depending on the use of representative and regionalised data. In addition, the statistical variability is also investigated by comparing the LCIA results obtained using the ILCIDAF datasets related to each region and the sole dataset included in Ecoinvent, to be considered as representative of the Italian average olive production. The functional unit (FU) selected for carrying out the analysis is represented by 1 kg of harvested olives. This FU is chosen according to the study of Notarnicola *et al.* (2017), by which mass-based FUs emerged as the most adopted among LCA studies related to the agri-food sector. System boundaries follow a cradle-to-distribution approach (figure 1), In particular, all the processes involved in olive production are included, specifically soil management, irrigation, fertilisation and pest control, pruning and harvesting. In addition, transport activities of inputs to the farm and olives to the olive mill, as well as waste treatment are also included. Cut-off criteria include the production of capital goods (i.e., machinery, equipment and infrastructures).

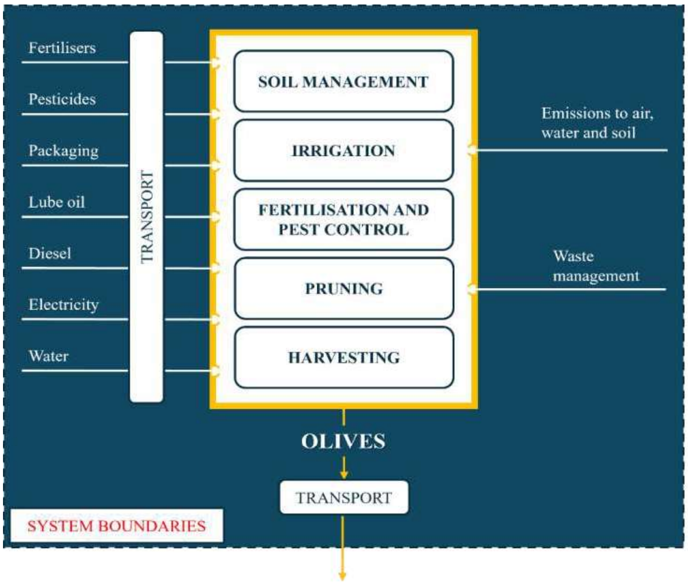

Figure 1. System boundaries of the investigated olive production system.

Inventory Analysis

To pursue the scope of this study, the LCI is built using data from the ILCIDAF database. In particular, data related to olive production in the 19 Italian regions are obtained using datasets developed from secondary sources that are specifically related to each geographical context. Indeed, data related to the average olive yields, to which all the inputs are normalised, are obtained through ISTAT (2021) considering the timeframe between 2015 and 2020. Data for fertilizers (nitrogen, phosphorus pentoxide, and potassium oxide) and pesticides (copper and Maconzeb) are gathered from the Guidelines for Integrated Production (GIP) available per each of the investigated regions (GIP, 2021). In addition, data related to irrigation processes (electricity and water) and machinery and equipment use (diesel and lubricating oil) as well as on packaging for chemicals are respectively collected by Ribaudo (2017) and Ecoinvent 3.9 database (Moreno Ruiz *et al.*, 2022). Regarding the outputs, secondary sources are also used for modelling waste management processes related to lubricating oil (CONOU, 2022), packaging (EC, 2021), and pruning Ribaudo (2017). Direct releases to air, water and soil are calculated using specific emission estimation models available in the international scientific literature (e.G, Notarnicola *et al.*, 2023; Zampori and Pant, 2019, etc.). Further information about data collection and calculation adopted for olive production in the ILCIDAF database are reported in Saija *et al.* (2024). Background data associated with the production of inputs and waste treatment processes are obtained using the Ecoinvent 3.8 database (Moreno Ruiz *et al.*, 2021). An overview of inputs and outputs included in the ILCIDAF datasets related to the 19 Italian regions is reported in Table 1.

Table 1. Overview of inputs and outputs for olive production included in the ILCIDAF database

Macro-category	**Input/Output**	**Unit**	**Data source**
Fertilizer	Nitrogen	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Phosphorus pentoxide	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Potassium oxide	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
Pesticide	Copper	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
	Mancozeb	kg	GIP, 2021; Moreno Ruiz *et al.*, 2021
Packaging	Packaging (fertilizer)	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
	Packaging (pesticide)	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
Irrigation	Water	m^3	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
	Electricity	kWh	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021

Macro-category	Input/Output	Unit	Data source
Fuel&lub	Diesel	kg	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
	Lubricating oil	kg	Ribaudo, 2017; Moreno Ruiz *et al.*, 2021
Transport	Transport of inputs	tkm	Eurostat, 2022; Moreno Ruiz *et al.*, 2021
Emission to air	Ammonia (from fertilizer)	kg	IPCC, 2006
	Dinitrogen monoxide (from fertilizer)	kg	IPCC, 2006
	Nitrogen oxides (from fertilizer)	kg	Zampori and Pant, 2019
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
	Ammonia (from diesel)	kg	Nemecek and Kägi, 2007
	Benzene (from diesel)	kg	Nemecek and Kägi, 2007
	Benzo(a)pyrene (from diesel)	kg	Nemecek and Kägi, 2007
	Cadmium (from diesel)	kg	Nemecek and Kägi, 2007
	Carbon dioxide, fossil (from diesel)	kg	Nemecek and Kägi, 2007
	Carbon monoxide, fossil (from diesel)	kg	Nemecek and Kägi, 2007
	Chromium (from diesel)	kg	Nemecek and Kägi, 2007
	Copper (from diesel)	kg	Nemecek and Kägi, 2007
	Dinitrogen monoxide (from diesel)	kg	Nemecek and Kägi, 2007
	Heat, waste (from diesel)	MJ	Nemecek and Kägi, 2007
	Methane (from diesel)	kg	Nemecek and Kägi, 2007
	Nickel (from diesel)	kg	Nemecek and Kägi, 2007

Macro-category	Input/Output	Unit	Data source
	Nitrogen monoxide (from diesel)	kg	Nemecek and Kägi, 2007
	NMVOC (from diesel)	kg	Nemecek and Kägi, 2007
	Particulates (from diesel)	kg	Nemecek and Kägi, 2007
	Sulphur dioxide (from diesel)	kg	Nemecek and Kägi, 2007
	Zinc (from diesel)	kg	Nemecek and Kägi, 2007
Emission to water	Nitrate (from fertilizer)	kg	IPCC, 2006
	Phosphate (from fertilizer)	kg	Prasuhn, 2006
	Cadmium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Chromium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (heavy metals)	kg	Notarnicola *et al.*, 2023
	Lead (heavy metals)	kg	Notarnicola *et al.*, 2023
	Mercury (heavy metals)	kg	Notarnicola *et al.*, 2023
	Nickel (heavy metals)	kg	Notarnicola *et al.*, 2023
	Zinc (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
Emission to soil	Cadmium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Chromium (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (heavy metals)	kg	Notarnicola *et al.*, 2023
	Lead (heavy metals)	kg	Notarnicola *et al.*, 2023
	Mercury (heavy metals)	kg	Notarnicola *et al.*, 2023

Macro-category	Input/Output	Unit	Data source
	Nickel (heavy metals)	kg	Notarnicola *et al.*, 2023
	Zinc (heavy metals)	kg	Notarnicola *et al.*, 2023
	Copper (from pesticide)	kg	Zampori and Pant, 2019
	Mancozeb (from pesticide)	kg	Zampori and Pant, 2019
Waste	Packaging of chemicals	kg	Moreno Ruiz *et al.*, 2022; Moreno Ruiz *et al.*, 2021
	Lubricating oil	kg	CONOU, 2022; Moreno Ruiz *et al.*, 2021
	Pruning	kg	EC, 2021; Moreno Ruiz *et al.*, 2021

Impact Assessment

The impact assessment is carried out by applying the Environmental Footprint (EF) 3.0 method (Fazio *et al.*, 2018). In particular, eight impact categories are assessed according to the Product Category Rule (PCR) for virgin olive oil and its fractions (EPD International, 2010), i.e., acidification, climate change, photochemical ozone formation, eutrophication (freshwater), land use, water use, resource use (fossil), and resource use (minerals and metals).

Interpretation

The interpretation phase is performed through a hotspot analysis, which allows the identification and investigation of the inputs, outputs or processes causing the highest contribution to the environmental impacts in the analysed systems among the 19 Italian regions. In addition, the variability in terms of LCIA results due to the use of regionalised inventory datasets is evaluated through a descriptive statistics analysis (Sheard, 2018). The analysis is carried out by calculating basic statistical indicators, such as mean, standard deviation and coefficient of variation.

Results and Discussion

Figure 2 reports the results in terms of the percentage contribution to the environmental impacts related to the agricultural processes for olive production among the investigated Italian regions. Regarding the acidification impact category, the main findings point out that, in all regions, the main contribution, to the impact is caused by the ammonia emissions to air, for which the percentage contribution ranges from 74.34% for CAL to 81.86% for LIG. This is due to the direct emissions associated with synthetic fertilizer use. On the contrary, direct emissions related to diesel use in machinery and fertilizer production are responsible for the highest contribution in the climate change impact category. In particular, the contribution to the climate change impacts respectively ranges from 59.33% for CAL to 69.48% for LIG, and from 11.79% for EMR to 21.21% for CAL. It is important to highlight that the impacts related to fertilizer production are connected to the background data derived from the Ecoinvent database. In addition, higher impacts related to the use of electricity in irrigation processes are also highlighted for APU, EMR, and FVG regions.

Emissions to air in terms of nitrogen oxides, due to diesel and fertilizer use, cause the highest impacts to photochemical ozone formation in all the Italian regions, with a percentage contribution higher than 64%. Concerning eutrophication (freshwater), the main impacts are connected to the use of fertilizers, for which the highest contribution emerges for CAL (91.15%), and to the production of copper as a pesticide, which causes the main impacts in the EMR region (22.48%). Focusing on land use and water use impact categories, fertilizers and pesticide production are responsible for the highest impacts in all the investigated regions. Higher impacts in terms of land and water use are also related to the irrigation process. It is important to underscore that, according to the ILCIDAF datasets for olive production, electricity and water use for irrigation are only accounted for those regions with a geographical conformation characterised by plains, as reported in ISTAT (2023). Results related to the resource use impact categories highlight that the main impacts are due to input production for which, as previously reported, background data are gathered by the Ecoinvent database. In particular, for fossil resource use the main contribution is connected to diesel and nitrogen fertilizer production which respectively cause the highest percentage contribution in EMR (51.13%) and LIG regions (20.27%). Remarkable impacts are also associated with transport activities, for which the contribution to the impact ranges from 8.31% for EMR to 18.29% for TAA. Furthermore, copper production mainly contributes to the minerals and metals resource use category, with values higher than 99% in all 19 Italian regions.

Overall, the results from the hotspot analysis point out that the main contribution to the potential environmental impacts is connected to fertilizers, fuel and direct emissions into the air. Furthermore, the main findings show high variability among regions in terms of the percentage contribution of inputs and outputs to the impacts, highlighting that the use of representative and regionalised data may strongly affect the LCA outcomes when agricultural processes are evaluated among different geographical contexts. This is also confirmed by the results obtained through the descriptive statistical analysis of the LCIA results (table 2). Indeed, the coefficient of variation, which is calculated by dividing the standard deviation by the mean, shows values that are higher than 43% in all the impact categories among the investigated Italian regions. In particular, the coefficient of variation ranges from 43.87% in climate change to 49.75% in eutrophication (freshwater). An in-depth analysis shows that, among the different regions, the minimum values in terms of environmental impacts in all categories are related to the TAA region, while the maximum emerges for the SAR region. In this regard, considering that, in ILCIDAF datasets for olive production, inputs related to each region are normalised to the average regional olive yield, a smaller amount of inputs is expected for those Italian regions characterised by a higher yield (e.G, for TAA the olive yield is equal to 5.2 tonnes per hectare), while a greater amount is accounted for regions with a lower yield (e.G, for SAR the olive yield is equal to 0.9 tonnes per hectare). Consequently, this variability may be reflected in the LCIA outcomes, further highlighting the importance of using data that are as much as possible representative of the investigated agrifood system.

Figure 2. Contribution analysis of inputs and outputs related to olive production in the 19 Italian regions under investigation (Characterisation results per 1 kg of harvested olives).

Table 2. Descriptive statistical analysis of the LCIA results

Impact categories	Mean	StD	CV (%)
Acidification [mol H+ eq]	2,61E-02	1.16E-02	44.39
Climate change [kg CO_2 eq]	8.46E-01	3.71E-01	43.87
Photochemical ozone formation [kg NMVOC eq]	3.98E-03	1.75E-03	43.99
Eutrophication (freshwater) [kg P eq]	6.59E-04	3.28E-04	49.75
Land use [Pt]	7.60E-01	3.50E-01	46.00
Water use [m^3 depriv.]	1.34E-01	6.49E-02	48.62
Resource use (fossil) [MJ]	6.51E+00	2.88E+00	44.25
Resource use (minerals and metals) [kg Sb eq]	2.30E-05	1.03E-05	44.99

Abb.: StD: Standard Deviation; CV: Coefficient of Variation

The usefulness of representative inventory data is also confirmed when LCIA outcomes using regionalised datasets from the ILCIDAF database are compared to those obtained using the sole dataset available for Italian olive production in Ecoinvent – Olive {IT}| olive production (figure 3). In particular, results underscore that using the Ecoinvent database instead of regionalised data may lead to an underestimation of the environmental impacts in all the investigated impact categories, except for land use and water use for an overestimation is pointed out. Indeed, the LCIA results vary from - 0.99 to about 342 times. The analysis also underscores that LCIA outcomes may strongly vary based on the investigated impact category to which specific direct or indirect emissions due to agricultural processes are classified. This is particularly true for the resource use (minerals and metals) category, in which a remarkable variability for certain regionalised datasets from the ILCIDAF database emerges when compared to the Ecoinvent dataset.

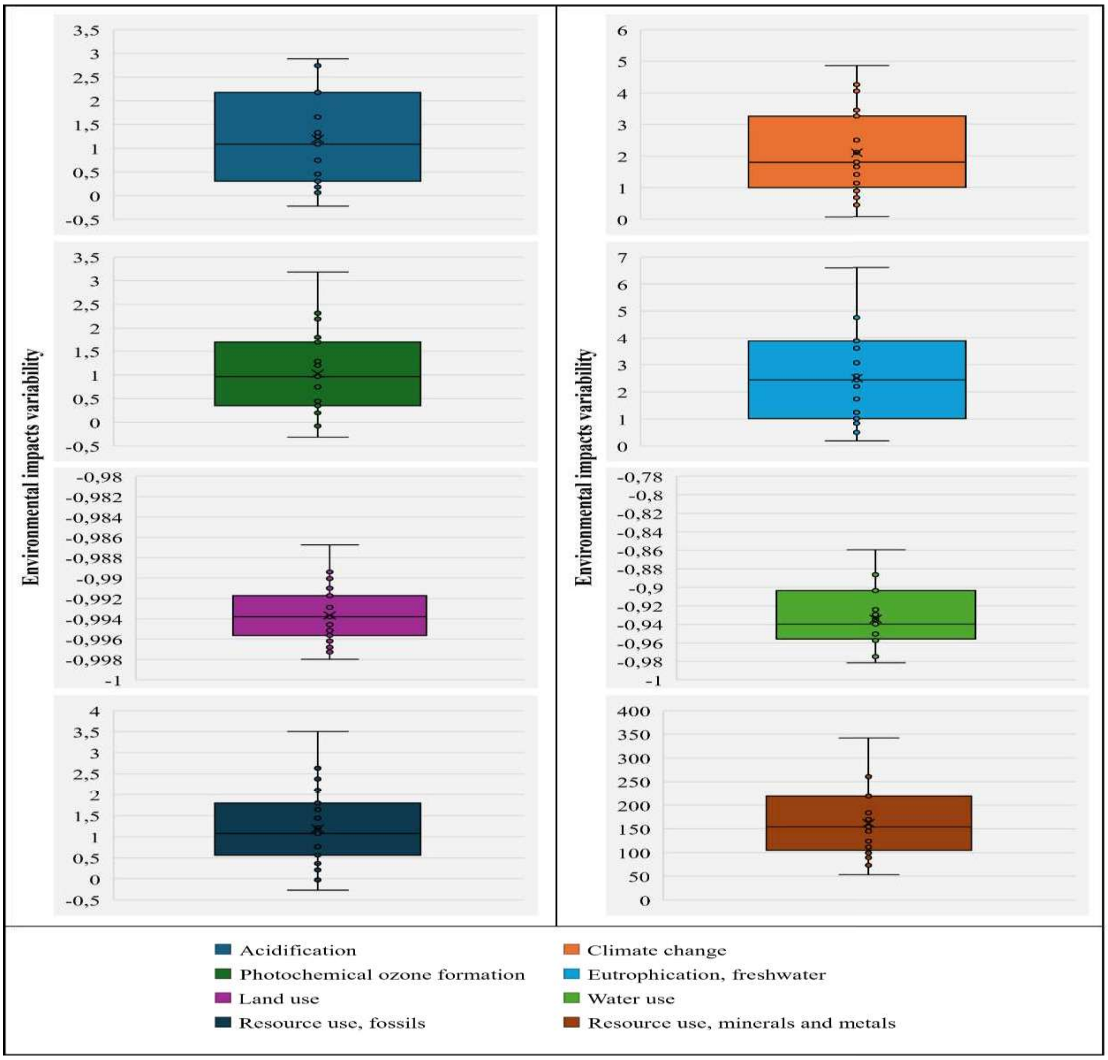

Figure 3. Environmental impact variability of regional olive production processes from the ILCIDAF database compared to the national average from the Ecoinvent database (the closer the value to 0, the lower the differences in terms of LCIA results between the two databases)

Conclusion

The aim of this study was to assess the potential environmental impact related to olive production in 19 Italian regions using regionalised datasets derived from the ILCIDAF database. The scope was to analyse and investigate the usefulness of representative LCI to be adopted in LCA studies related to agrifood systems. In this context, first, a hotspot analysis was carried out to point out which inputs, outputs or processes were responsible for the highest contribution to environmental impacts among regions. Then, a descriptive statistic analysis was performed in order to assess the variability in LCIA results occurring among regions in terms of environmental impacts. Lastly, the variability of the environmental impacts was also investigated comparing the LCA results obtained using regionalised data from the ILCIDAF database and the dataset related to olive production available in the Ecoinvent database. Results from the hotspot analysis highlighted that, in all the investigated Italian regions, the main contribution to the environmental impacts is due to direct emissions to air caused by fertilizers and diesel use, as well as due to fertilizers and fuel production. In addition, a significant statical variability emerged among the results. Indeed, a high coefficient of variation was identified for all the impact categories, ranging from 43.87% in climate change to 49.75% in eutrophication (freshwater). This confirms that the use of regionalised data, that are representative of the investigated agricultural or agrifood production systems, and account for all the intrinsic and extrinsic factors affecting them, may strongly characterize the results of a LCA study. This is also pointed out by the comparative analysis between ILCIDAF and Ecoinvent datasets. Indeed, using the Ecoinvent dataset instead of regionalised LCIs may cause an underestimation of the environmental impacts in most of the investigated impact categories.

The results from this study point out the importance of using representative data in LCA studies applied to agricultural processes. Despite this, future research should be oriented on evaluanting the uncertainty associated with the LCIA results obtained using such representative data. This would allow a more comprehensive understanding of the usefulness, accuracy and reliability of regionalised inventories available in the ILCIDAF database. In addition, futher analyses should be focused on expanding the system boundaries by also including the olive oil production, distribution, use and endof-life phase.

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