# Resilience and adaptation in Moroccan agriculture during the COVID-19 pandemic: perspectives from farmers

*Abdellatif* Boutagayout[1,2], *El Houssine* Bouiamrine[1], *Rachid* Lahlali[2], *Wijdane* Rhioui[2,3], *Anas* Hamdani[4], *Laila* Nassiri[1], *Moussa* El Jarroudi[5], and *Saadia* Belmalha[2]

[1]Moulay Ismail University, The Environment and Soil Microbiology Unit, Faculty of Sciences, B.P.11201 Zitoune, Meknes 50000, Morocco
[2]Ecole Nationale d'Agriculture de Meknès, Department of Plant and Environment Protection, BP/S 40, Meknès 50001, Morocco
[3]Sidi Mohamed Ben Abdellah University, Laboratory of Functional Ecology and Engineering Environment, Department of Biology, Fez 30050, Morocco
[4] University of Sultan Moulay Slimane, Laboratory of Biotechnology and Valorization of Plant Genetic Resources, Faculty of Sciences and Tech-niques, Beni Mellal, BP 523, Morocco
[5]University of Liège, Water, Environment and Development Unit, Department of Environmental Sciences and Management, UR SPHERES Research Unit, 6700 Arlon, Belgium

**Abstract.** The COVID-19 pandemic has significantly affected various sectors, including agriculture. This study aimed to explore the perceptions of smallholder farmers in Morocco's Fez-Meknes and Marrakesh-Safi regions regarding the potential effects of the pandemic on agricultural systems and the adoption of agroecological practices during the lockdown. The findings showed that farmers implemented diverse agroecological practices such as intercropping, organic fertilization, and local seed usage. However, the pandemic negatively affected the regular course of agricultural practices of 51.6% of the participants. The majority expressed concerns about market closures, labor availability, access to agricultural materials, and fertilizers. Farmers with more than two hectares of land were the most affected and less likely to embrace agroecological practices, whereas those with less than two hectares continuously adopted these practices and were less affected by COVID-19. Although 54.7% of the respondents reported no changes in their dependence on agroecological practices, 41.1% indicated that this dependency increased after the COVID-19 crisis. Understanding farmers' behavior during the pandemic can inform future agricultural policies that prioritize healthy and sustainable food production. This study underscores the importance of investing in agriculture and building resilience to ensure sustainable food systems in the face of future crises.

## 1 Introduction

The environment continuously reacts to unreasonable human activities (deforestation, urbanization, intensive agriculture, etc.) through catastrophic climate change, which can lead

to the emergence of resistant ecotypes, species extinction, and new diseases and pathogens. Zoonosis is caused by human interference with biodiversity and the destruction of ecosystems. Among the emerging zoonotic diseases, COVID-19 is an infectious and fatal disease that most likely passes to humans from animals, bats, or pangolins, a small mammal that is actively consumed in China [1].

SARS-COV2 represents the causative agent of COVID-19 originating from Wuhan City, China in December 2019, and then transmitted to the Fez-Meknes region, Morocco in March 2020, where the first case infected by this virus appeared (Moroccan from Italy). In a very short period, the pandemic has led to unprecedented risks that affect all aspects of human life (economic, social, environmental, etc.), both directly and indirectly, through measures taken to circumvent its impact [2]. Either it has affected the environmental sector negatively or positively; the negative impacts are related to increased biomedical waste generation, use of safety equipment and solid waste generation, and reduced recycling. However, COVID-19 has also shown positive environmental impacts such as reduced air, water, and noise pollution, etc. [3, 4]. The pandemic has led to unprecedented risks to the health sector by increasing the number of deaths and infections worldwide [5]. The COVID-19 spread and human response to combat this pandemic have changed the life-styles of audiences worldwide. During the lockdown, the government of Morocco adopted several preventive measures, such as border closures, confinement, social distancing, and movement restrictions. These measures have significantly affected the national economy through an increase in public debt and unemployment, a decrease in national production and international exports, and, therefore, a fall in income with a budget deficit (to more than 6% of GDP) [6].

Given its social, economic, and environmental importance, agriculture is also one of the main sectors affected by COVID-19, as more than a billion people (almost a third of the global workforce) work in this sector worldwide. This sector is considered to be among the leading providers of jobs and a major contributor to global population development [7]. This sector continues to face several challenges owing to climate change, loss of agrobiodiversity, poor mastery of production techniques, and agricultural protection, especially in developing countries, such as Morocco [8,9,10,11]. People most threatened by food insecurity and climate change are those with low adaptive capacity, including poor people with social status and locations in marginal areas [12]. Unfortunately, many farms remain attached to the intensive use of synthetic pesticides, which has worsened the effects of poisoning, plant fragility, environmental pollution, and massive biodiversity loss (70% of the terrestrial biodiversity loss). Both farmers and consumers are exposed to significant health risks [13,14,15]. The agricultural sector in Morocco has been subjected to drought because of climate change [16]. Recently, Moroccan farmers suffered from the spread of the pandemic, which resulted in a decline in international trade and demand, difficulty in trans-porting and marketing products, changes in consumption patterns by buyers due to loss of income, market closures, and so on [17,18].

The combined effects of the pandemic and climate change on agriculture pose potentially destructive problems that require short-, medium-, and long-term intervention [19] (Mishra et al. 2021). In this sense, many countries and organizations are making special efforts to keep the agricultural sector safe because of the potential increase in food insecurity during the spread of the COVID-19 pandemic and to keep markets well supplied with affordable and nutritious food sustainably. Potential strategies have been proposed for long-term environmental sustainability, such as the use of renewable energy, waste recycling and reuse, behavioral changes in daily life, and the adoption of agroecological approaches by the agricultural sector [4]. For years, agroecologists have warned that industrial agriculture has become too ecologically narrow, heavily dependent on external in-puts, and extremely vulnerable to pests, diseases, and climate change. The COVID-19 pandemic has revealed a

strong link between human, animal, and environmental health. The agricultural sector can either improve or negatively affect the health of the three sec-tors. Furthermore, COVID-19 has approved the unsustainability of industrial agriculture, which has been subjected to a complete shutdown owing to unforeseen crises [20].

Faced with climate change and health crises, such as COVID-19, the transition to an agroecological model that respects ecological, environmental, economic, and social ethics can be an interesting pathway toward sustainable agriculture that is more resilient than conventional agriculture [20,21,22]. As alternative and promising agricultural models based on more efficient management of agroecosystems, biodiversity is also being pro-moted in agroecological models [11,23]. Alternative agroecological approaches are less dependent on chemical inputs and are based on the maximum exploitation of available natural resources. These have been advocated as alternative approaches for promoting bi-ological diversity, optimizing biological interactions, and improving ecosystem services [11,24,25].

To our knowledge, no scientific study has evaluated the impact of COVID-19 spread on different aspects of agroecological practices in Morocco. The aims of this study were: (a) to examine the agroecological practices adopted by farmers in two Moroccan regions, Fes-Meknes and Marrakech-Safi, and (b) to investigate the perceptions of these farmers regarding the potential effects of COVID-19 on agricultural systems and the adoption of particular agroecological practices. This study aims to contribute to the knowledge of farmer resilience and adaptation in the face of the pandemic, and to explore the potential role of agroecological practices in enhancing agricultural sustainability in Morocco.

## 2 Materials and Methods

### 2.1 Research setting

The present study was conducted in Morocco in the North West of Africa, with 35.36 million inhabitants in 2018, including more than 13.2 million in rural areas, with a population growth rate of 1.25 % per year. According to United Nations forecasts, Morocco is expected to have 40.8 million inhabitants by 2030 [26]. The country is bordered by eastern Algeria and southern Mauritania. Morocco was divided into 12 regions based on the 2015 territorial division: Tangier-Tetouan-Al Hoceïma, Oriental, Rabat-Sale-Kenitra, Beni Mellal-Khenifra, Fez-Meknes, Casablanca-Settat, Marrakesh-Safi, Drâa-Tafilalet, Souss-Massa, Guelmim-Oued Noun, Laâyoune-Sakia El Hamra, and Dakhla-Oued Ed Dahab. Morocco is characterized by diverse climates ranging from moderately humid and humid climates to Saharan and sub-Saharan climates. Surveys were conducted over two regions of considerable agricultural importance: the Fez-Meknes and Marrakesh-Safi regions (Figure 1).

### 2.2 Data and sample

A cross-sectional survey was conducted with farmers to investigate the impact of COVID-19 on different aspects of agroecological practices in the study regions. The data collection period was June 2020 to March 2021. Of the 229 surveys received, 16 were excluded due to missing data. A total of 213 farmers participated in this study and were randomly distributed in the Fez-Meknes (n=100) and Marrakech-Safi (n=113) regions. The survey was prepared in two languages (French and Arabic) and often translated by communication into the local languages of the participants (Darija or Tamazight) depending on the cultural context.

The survey consisted of 38 questions: nine questions concerning the sociodemographic characteristics of respondents, 17 questions concerning agroecological practices, and 12

questions about the COVID-19 impact on agroecological practices and the agricultural sector (Table S1).

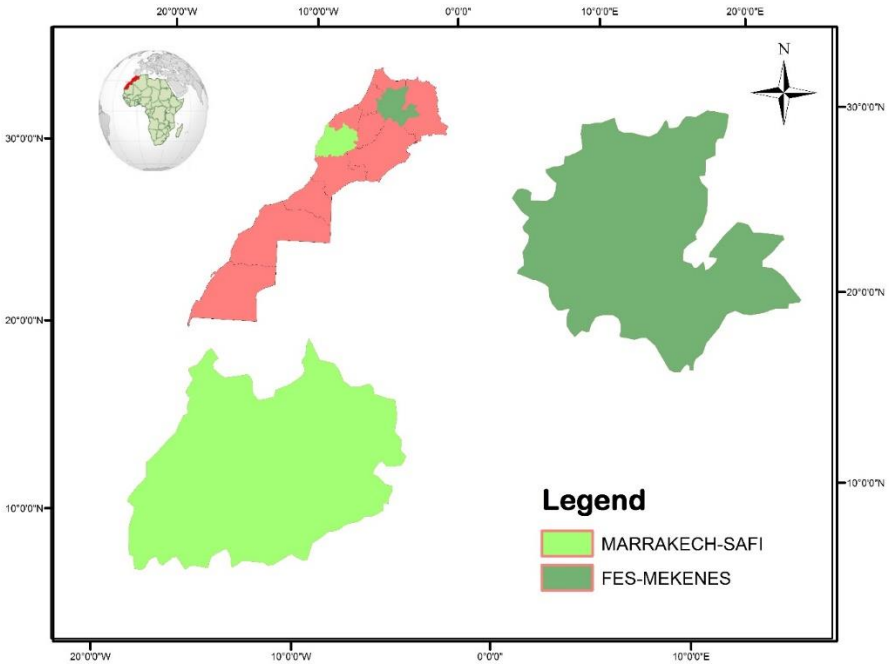



**Fig. 1.** Location of the studied areas of Marrakesh-Safi and Fez-Meknes

### 2.3 Data Collection and Processing

Data were collected and responses with missing information were deleted to eliminate the risk of error. The selected data were coded using numbers, saved in Excel, and subjected to descriptive analysis to calculate the percentages and frequencies of the different responses. Multiple response analysis was used to analyze the questions with multiple choice categorical variables. The chi-square test (Chi2) was used to test the null hypotheses regarding the relationship between the region and other categorical variables. Spearman's correlation was used to detect bivariate relationships between variables. Multiple correspondence analysis (MCA) (multidimensional statistical description method) was used to summarize information concerning the agricultural area, food security, adoption of agroecological practices, COVID-19 influence on agricultural practices, and farmers' dependence on agroecological practices during the lockdown. Statistical analyses were performed using IBM SPSS Statistics 21 software, and graphical figures were prepared using Excel 2016 software.

## 3 Results

### 3.1 Farmers' Descriptive Information

The survey was conducted in two regions of Morocco where the agricultural sector is highly important, namely the Marrakesh-Safi and Fez-Meknes regions. The Chi2 test only revealed

a relationship between the region considered and the sociodemographic characteristics of household food security status, family situation, and place of residence, but with low association values (Cramer's V less than 0.303). Among the interviewed farmers, 100 (46.1%) and 113 (53.1%) were from the Fez-Meknes and Marrakesh-Safi regions, respectively. Sociodemographic characteristics included age, education level, sex, and family status. Almost 86% of the participants were men, with 70% settling in rural areas and 30% in urban areas. Farmer age diverges from 15 to over 50 years; farmers between 35 and 45 years were the most frequent, representing 29.6% of described farmers; the youngest (15 to 25 years old), and the oldest (over 50 years) represented 12.7 and 11.7% of the target population, respectively. Regarding educational level, 42.7% of the investigated farmers had university instruction and 20.2% were uneducated. Approximately 53% of farmers practiced farming full-time; 47% had professions other than agriculture (Table 1).

The major cultivated crop species among the surveyed respondents are presented in Figure 2. Different types of crops (fruit trees, legumes, cereals, medicinal and aromatic plants, etc.) characterize the Fez-Meknes and Marrakesh-Safi regions, namely olives (59.2%), vegetables (59.2%), and cereals (58.2%), followed by fruit trees (50.2%), and legume crops (45.1%). Ornamental, and medicinal & aromatic plants accounted for 4.2 and 16 %, respectively.

In addition, 32% of the surveyed farmers have less than one hectare, and 88% of the informants are small farms with less than 5 ha, located in irrigated and non-irrigated areas, and at the mountain level with a percentage distribution of 53, 34%, and 13%, respectively. The farms used three irrigation systems for gravity, drip, and sprinkler irrigation, which were used regularly (always) with percentages of 38.4, 50.7%, and 11%, respectively. Approximately 63% of farmers declared that their farming habits were incomplete and required financial assistance (47.9%) and/or in-depth guidance and training (43%) to better manage their farms. Indeed, more than 53% of the respondents declared that agricultural products were destined for home consumption (auto-consumption), 38% for the local market, and only 0.6% for international markets (Figure S1).

**Table 1.** Sociodemographic characteristics of informants.

| | **Fez-Meknes 100 (46.9%)** | **Marrakesh-Safi 113 (53.1%)** | **Total 213 (100%)** | **Chi-square/ Cramer's V** |
|---|---|---|---|---|
| **Gender** | | | | |
| Man | 86 (86%) | 97 (85.8%) | 183 (85.9%) | 0.973 / 0.002 |
| Women | 14 (14%) | 16 (14.2%) | 30 (14.1%) | |
| **Place of residence** | | | | |
| Urban | 38 (38%) | 26 (23%) | 64 (30%) | 0.017*/ 0.163 |
| Rural | 62 (62%) | 87 (77%) | 149 (70%) | |
| **Age** | | | | |
| 15 to 25 years old | 8 (8%) | 19 (16.8%) | 27 (12.7%) | 0.064 / 0.204 |
| 25 to 35 years old | 26 (26%) | 33 (29.2%) | 59 (27.7%) | |
| 35 to 45 years old | 35 (35%) | 28 (24.8%) | 63 (29.6%) | |
| 45 to 55 years old | 23 (23%) | 17 (15%) | 40 (18.8%) | |
| Over 55 | 8 (8%) | 16 (14.2%) | 24 (11.3%) | |
| **Family situation** | | | | |
| Married with children | 46 (46%) | 54 (47.8%) | 100 (46.9%) | 0.000*/ 0.302 |
| Married but without children | 18 (18%) | 6 (5.3%) | 24 (11.3%) | |

| | | | | |
|---|---|---|---|---|
| Single | 26 (26%) | 51 (45.1%) | 77 (36.2%) | |
| Divorced | 10 (10%) | 2 (1.8%) | 12 (5.6%) | |
| **Academic level** | | | | |
| Illiterate | 19 (19%) | 24 (21.2%) | 43 (20.2%) | 0.409 / 0.117 |
| Primary | 12 (12%) | 10 (8.8%) | 22 (10.3%) | |
| Secondary | 31 (31%) | 26 (23%) | 57 (26.8%) | |
| University | 38 (38%) | 53 (46.9%) | 91 (42.7 %) | |
| **Other professions** | | | | |
| Yes | 46 (46%) | 54 (47.8%) | 100 (46.9%) | 0.794 / 0.018 |
| No | 54 (54%) | 59 (52.2%) | 113 (53.1%) | |
| **Household Food Security Status** | | | | |
| Never | 7 (7%) | 15 (13.3%) | 22 (10.3%) | 0.029*/ 0.225 |
| Rarely | 8 (8%) | 15 (13.3%) | 23 (10.8%) | |
| Sometimes | 31 (31%) | 45 (39.8%) | 76 (35.7%) | |
| Often | 28 (28%) | 24 (21.2%) | 52 (24.4%) | |
| Always | 26 (26%) | 14 (12.4%) | 40 (18.8%) | |

*Tests performed Chi-square with Cramer's V to indicate the strength of the relationship between different regions, significant at the 5% level.

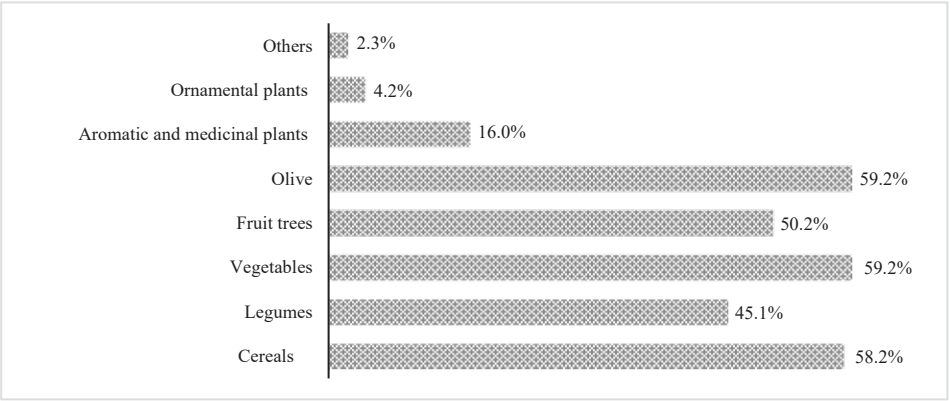



**Fig. 2.** Main cultivated crops among the respondents (n=213).

## 3.2 Status of the agroecological practices

The results revealed that 178 (83.6%) respondents had adopted at least one agroecological practice. Despite this, 94 (44.1 %) farmers had never heard of agroecology (Table 2). The most commonly adopted practices were intercropping and organic fertilizers (65.6 and 55.7%, respectively) (Figure 3).

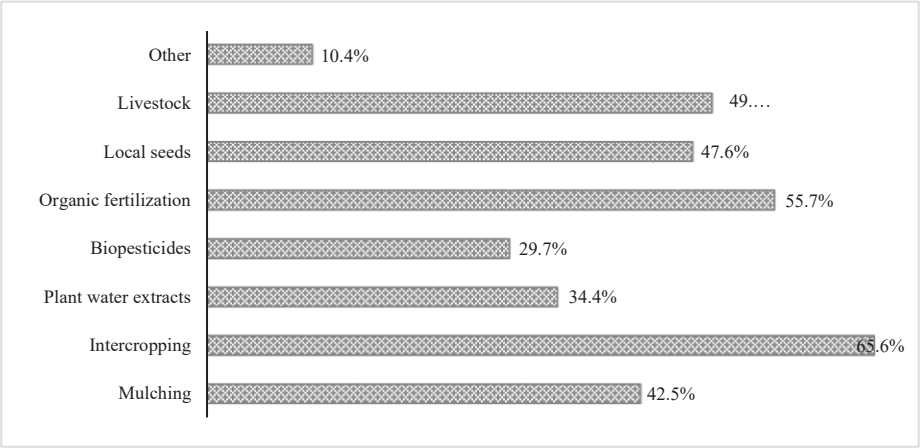



**Fig. 3.** Different agroecological practices adopted by farmers in Fez-Meknes and Marrakesh-Safi.

The most common diversification and intercropping systems used were the categories of fruit tree annual crops (agroforestry), containing the intercropping of olive trees with annual crops, such as legumes/cereals (Figures S2) (Figures 4 and 5). More than 40% of farmers with an area of less than two hectares (less than 1 and between 1 and 2 ha) often adopted different agroecological practices, whereas more than 42% of farms with more than four hectares (4-5 and above 5) adopted these practices occasionally (sometimes) (Figure S3).

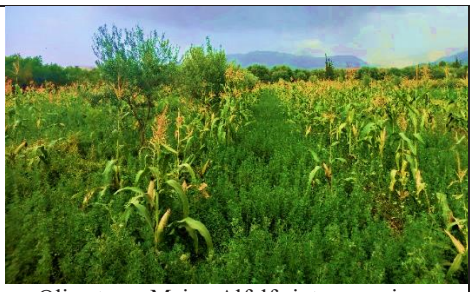

Maize-Tomato-Artichok-Pepper intercropping


Olive trees-Cereals intercropping


Plum tree-Onions intercropping


Olive trees-Onions intercropping

Faba Faba bean-Berseem clover intercropping with Washington Palm and Olive trees at the plot borders



Olive trees-Maize-Alfalfa intercropping

**Fig. 4.** Photographs of some intercropping systems adopted by smallholder farms in the Marrakesh-Safi (left) and Fez-Meknes (right) regions, Morocco.

Except for the number of people who adopted agroecology around the surveyed farmers, the chi-square test revealed no relationship between the region and the status of agroecological practices. Spearman's correlation indicated a significant ($p=0.012$) and negative correlation between farm area and the adoption of agroecological practices. On large farms, agroecological practices are not always adopted but only sometimes. While conducting their agricultural sizes, the small farms often relied on different agroecological approaches. More than 95% of the respondents were aware of the importance of agroecological practices and wanted to improve them. Almost 90% declared that this mode was part of their future agriculture (Table 2).

**Fig. 5.** Photographs of diversified farming systems adapted to local environments. A and d ; Douar sbiti ourika, b and c ; Douar Taourirt.

**Table 2.** Status of agroecological practices in the studied region.

| | Fez-Meknes | Marrakesh-Safi | Total | Chi-square/ Cramer's V |
|---|---|---|---|---|
| Have you ever heard of agroecology? | | | | |
| No | 43 (43%) | 51 (45.1%) | 94 (44.1%) | 0.754 / 0.021 |
| Yes | 57 (57%) | 62 (54.9%) | 119 (55.9%) | |
| Do you adopt agroecological practices? | | | | |
| Never | 16 (16%) | 19 (16.8%) | 35 (16.4%) | 0.837 / 0.082 |
| Rarely | 14 (14%) | 10 (8.8%) | 24 (11.3%) | |
| Sometimes | 27 (27%) | 33 (29.2%) | 60 (28.2%) | |
| Often | 31 (31%) | 36 (31.9%) | 67 (31.5%) | |
| Always | 12 (12%) | 15 (13.3%) | 27 (12.7%) | |
| How many people practice agroecology around you? | | | | |
| I do not know | 54 (54%) | 61 (54%) | 115 (54.0%) | 0.001*/ 0.310 |
| Nobody | 23 (23%) | 9 (8%) | 32 (15.0%) | |
| 1 to 3 people | 11 (11%) | 6 (5.3%) | 17 (8.0%) | |
| 3 to 5 people | 2 (2%) | 4 (3.5%) | 6 (2.8%) | |
| 5 to 7 people | 3 (3%) | 7 (6.2%) | 10 (4.7%) | |
| More than 7 people | 7 (7%) | 26 (23%) | 33 (15.5%) | |
| Would you like to improve your agroecological practices? | | | | |
| Yes | 97 (97%) | 106 (93.8%) | 203 (95.3%) | 0.271 / 0.075 |
| No | 3 (3%) | 7 (6.2%) | 10 (4.7%) | |
| Do you think agroecological practices are part of our future? | | | | |
| Yes | 89 (89%) | 103 (91.2%) | 192 (89.7%) | 0.599 / 0.036 |
| No | 11 (11%) | 10 (8.8%) | 21 (9.8%) | |

*Tests performed Chi-square with Cramer's V to indicate the strength of the relationship between different regions, significant at the 5% level.

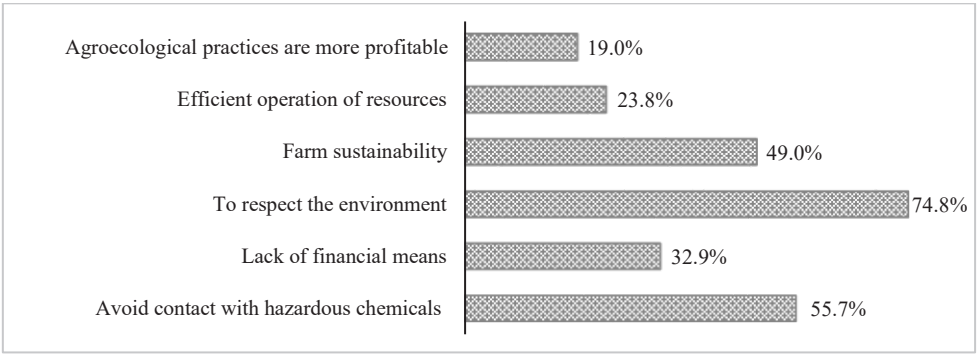



**Fig. 6.** Why (s) do you practice agroecology?

According to the results presented in Figure 6, the main reasons for adopting agroecological practices are respecting the environment (74.8), avoiding contact with dangerous chemicals (55.7%), maintaining the sustainability of the agricultural farm (49%), and the lack of financing means (33%). In addition, the criteria that prevented the smooth running of agroecological practices revealed a lack of practical and/or theoretical knowledge concerning

agroecological approaches (more than 61%) and the difficulty of setting up and succeeding agroecological practices (more than 50%), especially at supermarket levels. In addition, 42.5% of the respondents mentioned that conventional farming, such as the use of chemical pesticides and deep plowing, was more effective in producing successful agricultural products (Figure 7).

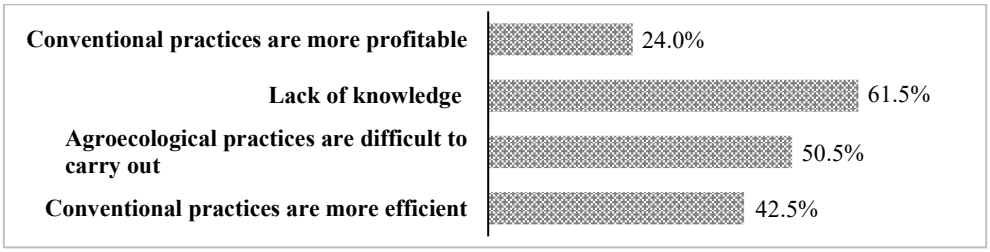



**Fig. 7.** What hinders agroecological practice?

### 3.3 COVID-19 and agroecological practices

Relationships were recorded between the region and the effect of COVID-19 on agricultural behaviors with a weak association strength (Cramer's V did not exceed 0.369), which was the case for the variables of how COVID-19 affected farming practices, receipt of financial assistance, and reliance on agroecological practices during and after the lockdown. More than 51% of the informants emphasized that COVID-19 spread negatively influenced their agricultural behavior, with an economic impact on their agricultural production. Accordingly, 44.6% stressed that their agricultural habits had changed during the lockdown. In addition, 171 agricultures noted that they had not received any funding assistance in light of COVID-19. Even though 45.1% (96) of the informants did not take any action against the coronavirus, this virus affected only 18.3% of farmers. Thus, 66.4% of farmers mentioned that the combined effects of the COVID-19 spread and drought significantly affected their agricultural production. Among the surveyed farms, dependence on agrological practices during the lockdown remained unchanged at 54.7% and increased by 35.4%; however, this dependence decreased for 9.9% of informants. According to the farmers, this dependence increased by 5.7% (from 35.4 to 41.1%) during the post-COVID period (Table 3).

During the lockdown, COVID-19 effects were manifested mainly by market closures (150 respondents). In addition, many farmers mentioned concerns related to the lack of transport, distance from sale places, sale price, access to the farm, limited labor force, and access to irrigation water, agricultural materials, and fertilizers (Figure 8).

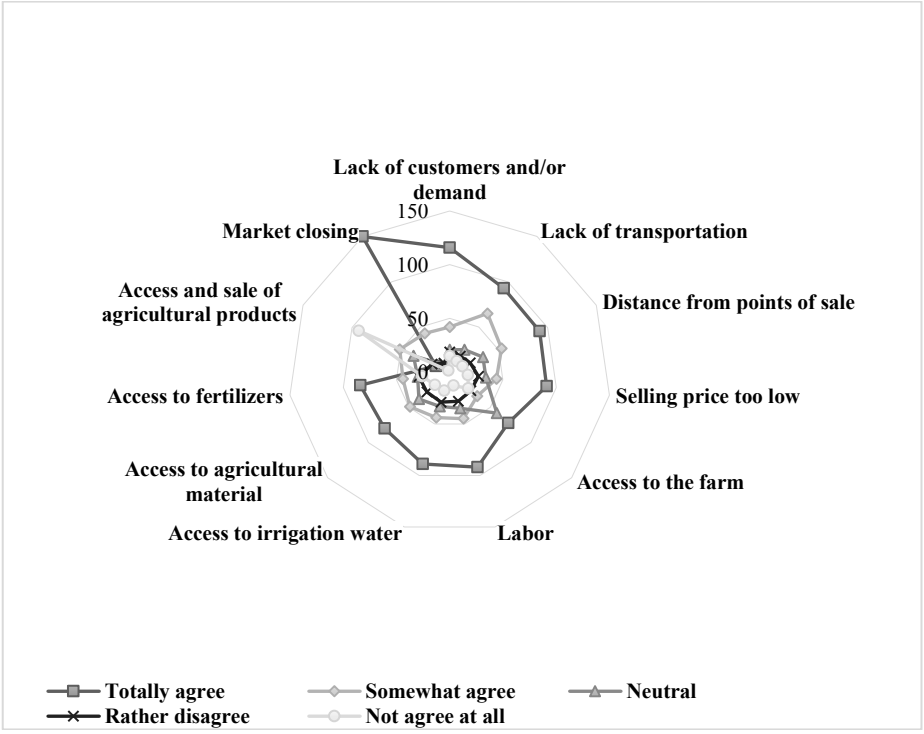



**Fig. 8.** Where did the impact of COVID-19 spread manifest?

The multiple correspondence analysis (MCA) of agroecological practice adoption and COVID-19 impacts is illustrated in Figure 9. The variables entered revealed two dimensions that summarized 54.6% of the total information and were deemed satisfactory (greater than 50%). The projections of the first and second dimensions explained 30% and 24.6% of data variability, respectively. Multiple correspondence analysis (MCA) did not make it possible to distinguish precise groupings. However, there was a tendency for farmers with large areas (greater than 2 ha) to ensure food security, to be negatively affected by the spread of COVID-19, and to not adopt agroecological practices, except rarely or sometimes. Conversely, small farms (less than 2 ha) do not ensure food security; rarely or sometimes, they tend to constantly (always) adopt agroecological practices. Therefore, the COVID-19 spread did not change farming habits.

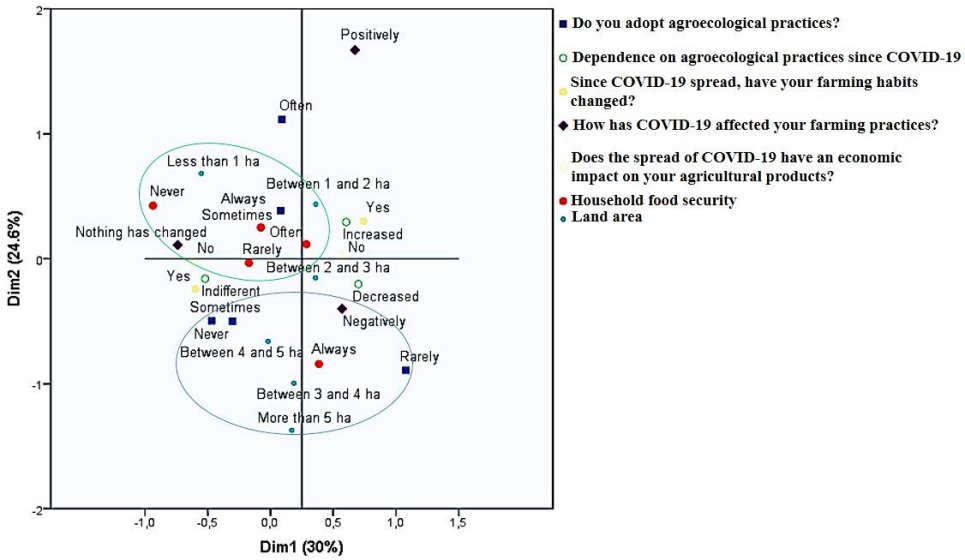



**Fig. 9.** Multiple correspondence analysis (MCA). Projections of the first two dimensions.

## 4 Discussion

The agricultural sector is a crucial part of Morocco's economic and social fabric, contributing significantly to the country's GDP and job creation. In fact, it contributes 15% to the GDP, with a value of 131.62 billion DH, and generates 40% of jobs in the country, particularly in rural areas where 74% of these jobs are located [27]. The importance of this sector as a source of income and food for Moroccan households cannot be overlooked. The contribution of the agricultural sector to GDP varies by region, with the Fez-Meknes region recording the highest share of value-added agriculture (VAA) at 16.5%, followed by Marrakesh-Safi (14.2%), Rabat-Sale-Kenitra (13.4%), Casablanca-Settat (12%), and others [28, 29]. This regional variation in VAA highlights the need to understand the specific challenges and opportunities faced by farmers in different regions, particularly during times of crisis.

This study aimed to investigate the agroecological practices adopted by farmers in the Fez-Meknes and Marrakech-Safi regions in Morocco and assess the potential impacts of the COVID-19 pandemic on these practices during the lockdown period. The study found that most of the farmers interviewed were men who were smallholder farmers situated in rural areas of Morocco [30, 31]. This profile of farmers is similar to that in previous studies conducted in Morocco and Malawi. In Morocco, only 1% of farmers have more than 50 hectares, whereas 70% of farmers have an area of less than 5 hectares. Of these smallholder farmers, 55% have less than three hectares, and they only exploit 12% of the Moroccan useful agricultural area (UAA) [27].

The agricultural products of the surveyed farmers were primarily intended for family consumption (53.1%) and local markets (38.4%). Family farming plays a crucial role in Morocco, not only in food and economic issues, but also in security and sociocultural is-sues. Family farming represents a lifestyle that can be reflected in farmers and rural communities [32]. However, most smallholders are less visible in agricultural policies be-cause they operate on family farms [33]. Morocco has a large area of pastures, forests, and agricultural land, with a useful agricultural area (UAA) of nearly 8.7 million hectares, which reflects a high level of agro-climatic systems that contribute to the production of a wide range of agricultural products. Moroccan farming is dominated by the cereal growing sector (90% is

installed in Bours), which accounts for nearly 60% of the overall useful agricultural area, followed by arboriculture (16%), fallow (12%), fodder (5%), legumes (3%), and market gardens (3%), while other sectors occupy only 2% of the UAA [29].

The main crops cultivated by the surveyed farmers were cereals, legumes, vegetables, olives, and other fruits. Drought, caused by the weakness and irregularity of rainfall, is one of the primary obstacles to national agricultural development, resulting in the limitation of irrigation water resources, need for the rational use of surface and underground water, and adoption of more efficient irrigation systems [33]. More than half (53%) of the farms examined in this survey were located in non-irrigated areas (Bour). Three irrigation modes were adopted for irrigated areas: gravity, drip, and suction irrigation. It is note-worthy that most of the national agricultural area is sown and managed under the rainfall regime (Bour). Irrigated areas have allowed large crop varieties to grow in relatively small areas [33].

The Moroccan government has recognized the importance of the agricultural sector and prioritized it in national development policies such as the Green Morocco Plan (GMP) launched in 2008 [34]. GMP aims to make the sector more competitive on a global scale while also addressing social objectives, including reducing the wealth gap and contributing to food security. However, the intensive agricultural model promoted by these policies has raised concerns about its environmental impact. The excessive use of mechanization, chemical inputs, and irrigation, as well as the overloading of productive heritage sites, has led to environmental degradation and loss of biodiversity [35,36].

The heavy use of chemical pesticides, in particular, has resulted in the loss of agroecosystem biodiversity and can potentially lead to the emergence of new infectious diseases [37,38,39]. As such, promoting local production and minimizing the harmful effects of chemicals on public health and the environment have become increasingly important. Agroecology, an ecosystem-based approach to agriculture that combines traditional farming practices with modern scientific knowledge, has gained attention as a potential solution. It aims to achieve a sustainable world without chemical inputs while promoting good practices for the management of water and energy resources, conservation of farm-land, and promotion of agroecosystem biodiversity [41,43].

In addition, the dominance of a mono-cropping system can threaten the sustainability of the agricultural system and generate economic difficulties, particularly for small and marginal farmers [44]. The farmers in this study, particularly those with areas less than 2 ha, adopted various agroecological practices, such as intercropping, organic fertilization, mulching, use of plant extracts, bio-pesticides, conservation of genetic resources (local seeds), and integration of animal husbandry with agricultural practices. These practices reflect the need to respect the environment, avoid contact with dangerous chemicals, and maintain agricultural farm sustainability.

It is important to note that the majority of farms in Morocco are owner-managed, with very little additional labor (only 5% of farmers in this study) [45]. Thus, smallholders increasingly need to diversify their agricultural production strategies to meet their economic and social requirements. Traditional and non-chemical practices indicate that agriculture produces multiple positive environmental externalities [35]. Encouraging the adoption of agroecological practices could potentially lead to a more sustainable and resilient agricultural sector in Morocco.

The surveyed informants were aware of the importance of agroecology and expressed their desire to improve agroecological practices. However, many smallholder farmers stated that their farming habits were incomplete and required financial support and training in agroecological practices. According to the respondents, the lack of knowledge and difficulty in setting up and succeeding with agroecological practices were the main reasons for preventing their adoption. Additionally, the effectiveness of these practices compared to intensive practices, especially in the short term, has been questioned. Wezel et al. [21]

conducted a study that showed that the belief that agroecology means less productivity, lack of funding for agroecological research, material support, manpower, training and knowledge sharing, and policies that support agroecological practices were among the main challenges to agroecology adoption. In contrast, Schoonhoven and Runhaar [46] suggested that voluntary motivation, capacity to implement these agricultural practices, the resources and skills required, and other conditions related to agricultural policies were the main requirements for adopting agroecological practices. Exploitation size in this study was negatively correlated with the adoption of agroecological practices. Similarly, Coulibaly et al. [47] showed that traditional agriculture based on agroecological practices was conducted in small areas (2.37 ha), which belong to family farming with little income. Smallholder food production in rural areas is primarily based on the diversification of agroecological approaches, which can generate local knowledge, nourish identity and culture, promote social justice, and strengthen the economic sustainability of local farmers.

In response to the COVID-19 pandemic, the Kingdom of Morocco has considered three main aspects: health, economy, and society. Several measures have been implemented to build hospital capacity, such as various preventive response measures, information and awareness campaigns on hygiene measures, and barrier gestures. Economic and social support measures have been developed to mitigate the impact of the pandemic, starting with the creation of a special fund for managing the coronavirus pandemic [17]. These measures have limited damage and provided some control over the global pandemic. However, surveyed farmers reported that the combined effects of COVID-19 and drought significantly affected their agricultural production. More than half of the respondents reported negative economic impacts and influences on the normal course of their agricultural practices. Similarly, a study conducted in Senegal reported that more than 84% of the monitored farms were considerably affected by the COVID-19 spread [48]. The COVID-19 effects during the lockdown were mainly reflected by market closure, lack of means of transport, distance from points of sale, restricted labor, access to irrigation water, exploitation of agricultural materials, and fertilizers. The impact of the pandemic on smallholder farming systems has been identified in several aspects, such as marketing, labor accessibility, market access, and harvesting, as pointed out by Goswami et al. [49]. Against the COVID-19 crisis in agricultural systems, support for market access, labor management, agricultural investments, efficient use of irrigation, and soil fertility are among the main strategies proposed [49]. Ecological farming is often associated with greater food harmony and nutritional balance, primarily achieved through self-production, which ensures healthier diets with fewer food purchase expenses [50]. Tittonell et al. [51] noted that the movement toward agroecological practices has been among the responses of family farming in tackling the spread of COVID-19. Family farming through agroecological practices plays a key role in demonstrating adaptive and resilient strategies not only against COVID-19 but also against other possible disasters in the future [51].

Against the backdrop of the COVID-19 pandemic, resilience and adaptation of the Moroccan agricultural sector have become even more critical. In this context, it is essential to understand the perspectives and experiences of farmers in navigating the impact of the pandemic on their livelihoods and agricultural practices.

## 5 Conclusions

The COVID-19 pandemic has had a significant impact in many areas, including the agricultural sector. This study aimed to identify potentially resilient farming systems and examine farmers' perceptions of the effects of COVID-19 on agroecological practices in the Fez-Meknes and Marrakech-Safi regions of Morocco.

We found that a multitude of agroecological practices were being implemented, including intercropping, organic fertilization, mulching, plant extracts, bio-pesticides, conservation of genetic resources (local seeds), integration of livestock, and other practices such as crop rotation, drip irrigation, cover crops, and direct seeding. These practices helped farmers maintain their yields and sustain their livelihoods during the pandemic.

However, farmers also pointed out several challenges they faced because of COVID-19, such as market closures, distance from places of sale, selling prices, and a lack of means of transport, labor, irrigation, agricultural materials, and fertilizers. Interestingly, we found that large farms (greater than 2 ha) were less able to adapt agroecological practices and were more affected by the pandemic than small farms (less than two hectares), which had opted for the adoption of agroecological practices despite not always ensuring their food security.

This study highlights the importance of strengthening the resilience of the relation-ship between human activities and the environment against future pandemics and cli-mate change. It also emphasizes the need to remodel future agricultural policies to help the younger generation better understand and practice agroecological approaches and ensure that their needs do not affect the needs of future generations.

Overall, the information gathered from this study contributes to the development of anticipatory strategies for stakeholders in favor of health and sustainability during the post-pandemic period. It sheds light on local agroecological practices and farmers' perceptions of COVID-19, which can inform future agricultural policies and practices.

**Supplementary Materials: Table S1.** Summary of the main survey questions. **Figure S1.** Farming habits, product targets, irrigation systems, agricultural zones, and land areas. **Figure S2.** Different kinds of intercropping systems. **Figure S3.** Adoption of the agroecological practices according to exploitation size (ha).

**Author Contributions:** For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used “Conceptualization, AB and SB.; methodology, validation, and formal analysis, AB and RL.; writing—original draft preparation, AB.; writing—review and editing, AB, WR, AH, LN, SB, JAF, LB, and RL.; visualization, SB, EB.; All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding

**Informed Consent Statement:** Not applicable

**Data Availability Statement:** The data used to support the findings of this study are included within the article.

**Acknowledgments:** The authors thank the farmers who participated in this study for their participation by answering our questions, for their time and efforts.

**Conflicts of Interest:** The authors declare that there is no conflict of interest.

## References

1. A. El-Sayed & M. Kamel, Coronaviruses in humans and animals: the role of bats in viral evolution. Environ. Sci. Pollut. Res., **28(16),** 19589-19600 (2021)
2. Organisation for Economic Co-operation and Development (OECD) TACKLING CORONAVIRUS (COVID-19) CON-TRIBUTING TO A GLOBAL EFFORT; COVID-19 and the Food and Agriculture Sector: Issues and Policy Responses. Ac-cessed 10 June 2021. Available Online at: https://www.oecd.org/ (2020)
3. S. Muhammad, X. Long & M. Salman, COVID-19 pandemic and environmental pollution: A blessing in disguise?. Sci. Total Environ., **728**, 138820 (2020)
4. Rume T & Islam SDU Environmental effects of COVID-19 pandemic and potential strategies of sustainability. Heliyon, **6 (e04965),** 1-8 (2020)

5. World Health Organization (WHO), Coronavirus Disease (COVID-19) Dashboard. Accessed 01 December 2020. Avai-lable Online at: https://covid19.who.int (2021)
6. Y. Oudda, A.I. Maha & L. Bennis, Les Retombées de La Crise Sanitaire Covid-19 Sur l'Economie Marocaine. Revue Du Contrôle, de La Comptabilité et de l'audit **4(2)** (2020)
7. Organisation Internationale du Travail (OIT), Travail productif et décent dans l'agriculture. Première edition, 1-11 (2019)
8. S. Nangombe, T. Zhou, W. Zhang, B. Wu, S. Hu, L. Zou & D. Li, Record-breaking climate extremes in Africa under stabi-lized 1.5 C and 2 C global warming scenarios. Nat. Clim. Change, **8(5),** 375-380 (2018)
9. B.W. Amoabeng, A.C. Johnson & G.M. Gurr, Natural enemy enhancement and botanical insecticide source: a review of dual use companion plants. Appl. Entomol. Zool., **54(1),** 1-19 (2019)
10. JA. Gnago, M. Danho, T. Atcham Agneroh, I.K. Fofana & A.G. Kohou, Efficacité des extraits de neem (Azadirachta indica) et de papayer (Carica papaya) dans la lutte contre les insectes ravageurs du gombo (Abelmoschus esculentus) et du chou (Brassica oleracea) en Côte d'Ivoire, Int. J. Biol. Chem. Sci. **4(4):** 953-966 (2010)
11. A. Ratnadass, P. Fernandes, J. Avelino & R. Habib, Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. Agron. Sustain. Dev., **32(1),** 273-303 (2012)
12. J. Ribot, Cause and response: vulnerability and climate in the Anthropocene. J. Peasant Stud., **41(5),** 667-705 (2014)
13. K. Poveda, MI. Gómez & E. Martinez, Diversification practices: their effect on pest regulation and production. Rev. Co-lomb. Entomol., **34(2),** 131-144 (2008)
14. E. Malézieux, Y. Crozat, C. Dupraz, M. Laurans & D. Makowski, Mixing plant species in cropping systems: concepts, tools and models. A review. Springer Verlag/EDP Sciences/INRA. Agron. Sustain. Dev., **29 (1),** 43-62 (2009)
15. FAO & PNUE, Convention de Rotterdam applicable à certains produits chimiques et pesticides dangereux qui font l'objet d'un commerce international, édition révisée, Nations Unies. Accessed 10 December 2020. Available Online at: http://www.pic.int/Accueil/tabid/1731/language/fr-CH/Default.aspx (2017)
16. K. Born, M. Christoph, A.H. Fink, P. Knippertz, H. Paeth & P. Speth, Moroccan climate in the present and future: com-bined view from observational data and regional climate scenarios. In Climatic changes and water resources in the Middle East and North Africa. Springer, Berlin, Heidelberg. 29-45 (2008)
17. P. Adimi, La gestion marocaine de la crise pandémique du COVID-19. Dossier du CIAAF, (**2).** 17 (2020)
18. A.A. Ali, A. Bassou, M. Dryef, K. El Aynaoui, R. El Houdaigui, A. Saaf, La stratégie du Maroc face au CO-VID-19/Morocco's Strategy Against COVID-19. Pol. C. New South. **37** (2020)
19. A. Mishra, E. Bruno & D. Zilberman, Compound natural and human disasters: Managing drought and COVID-19 to sus-tain global agriculture and food sectors. Sci. Total Environ., **754**, 142210 (2021)
20. M.A. Altieri & C.I. Nicholls, Agroecology and the emergence of a post COVID-19 agriculture. Agric. Hum., **37(3),** 525-526 (2020)

21. A. Wezel, M. Goris, J. Bruil, G.F. Félix, A. Peeters, P. Bàrberi, ... & P. Migliorini, Challenges and action points to amplify agroecology in Europe. Sustainability, **10(5),** 1598 (2018)
22. R. D'Annolfo, B. Gemmill-Herren, D. Amudavi, H.W. Shiraku, M. Piva & LA. Garibaldi, The effects of agroecological farming systems on smallholder livelihoods: A case study on push–pull system from Western Kenya. Int J Agric Sus-tain, **19(1),** 56-70 (2021)
23. B. Song, Z. Jie, L. Natasha, Y.Y. Wiggins, T. Guangbo & S. Xusheng, Intercropping with Aromatic Plants Decreases Her-bivore Abundance, Species Richness, and Shifts Arthropod Community Trophic Structure. Envir. Entom. **41(4):**872-79 (2012)
24. M.A. Altieri, Agroecology: the science of natural resource management for poor farmers in marginal environments. Agric. Ecosyst. Environ., **93(1-3),** 1-24 (2002)
25. M.D. Raseduzzaman & E.S. Jensen, Does intercropping enhance yield stability in arable crop production? A me-ta-analysis. European Journal of Agronomy, **91**, 25-33 (2017)
26. Harbouze R, Pellissier JP, Rolland JP & Khechimi W Rapport de synthèse sur l'agriculture au Maroc. [Rapport de re-cherche] CIHEAM-IAMM. **104** (2019)
27. J. Marzin, P. Bonnet, O. Bessaoud & C. Ton-Nu, Etude sur l'agriculture familiale à petite échelle au Proche-Orient et Afrique du Nord : Synthèse. Ed. FAO / Cirad / CIHEAM-IAMM. 98 (2017)
28. N. Akesbi, Evolution et perspectives de l'agriculture marocaine. Rapport, **50**, 85-198 (2006)
29. A. Louali, Le secteur agricole marocain : Tendances structurelles, enjeux et perspectives de développement. Rapport DEPF Etudes, 1-33 (2019)
30. R.B. Kerr, J. Kangmennaang, L. Dakishoni, H. Nyantakyi-Frimpong, E. Lupafya, L. Shumba, ... & I. Luginaah, Participa-tory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi. Agric. Ecosyst. Environ., **279**, 109-121 (2019)
31. I. Berni, A. Menouni, IG. El, RC. Duca, MP. Kestemont, L. Godderis & S.J. El Understanding farmers' safety behavior regarding pesticide use in Morocco. Sustain. Prod. Consum., **25**, 471-483 (2021)
32. S.R. Sippel, Breaking ground: multi-family farm entrepreneurs in Moroccan export agriculture. J. Rural Stud., **45**, 279-291 (2016)
33. M. Errahj, Étude sur l'agriculture familiale à petite échelle au Proche-Orient et Afrique du Nord. Pays focus: Maroc. Rapport de FAO, CIHEAM-IAMM et CIRAD. ISBN 978-92-5-209640-5, 98 (2017)
34. N. Akesbi, Which agricultural policy for which food security in Morocco? In: Gertel, J., Sippel, S.R. (Eds.), Seasonal Workers in Mediterranean Agriculture. The Social Costs of Eating Fresh. Routledge, London and New York, pp. 167-174 (2014)
35. M. Moussaoui, K. Allali, M. Bendaoud, R. Doukkali & M. Mahdi, Analyse socio-économique des rôles de l'agriculture et conséquences en matière de politique. Etude de Cas Maroc', Rapport de synthèse, Projet FAO-ROA/Maroc. FAO, Rome, Italy. (2003)
36. N. Akesbi, Une nouvelle stratégie pour l'agriculture marocaine: Plan Maroc Vert. New Medit: Mediterranean Journal of Economics, Agriculture and Environment. Rev. Médit. Econ. Agr. Env., **11(2),** 12 (2012)

37. C.A. Brühl & J.G. Zaller, Biodiversity decline as a consequence of an inappropriate environmental risk assessment of pesticides. Front. Environ. Sci., **7,** 177 (2019)
38. J.R. Rohr, D.J. Civitello, FW. Halliday, PJ. Hudson, KD. Lafferty, CL. Wood & E.A. Mordecai, Towards common ground in the biodiversity–disease debate. Nat. Ecol. Evol, **4(1),** 24-33 (2020)
39. P. Grandcolas & JL. Justine, COVID-19 or the pandemic of mistreated biodiversity. The Conversation. 3. hal-02559697 (2020)
40. M. Everard, P. Johnston, D. Santillo & C. Staddon, The role of ecosystems in mitigation and management of Covid-19 and other zoonoses. Environ. Sci. Policy., **111**, 7-17 (2020)
41. S. Berton, R. Billaz, P. Burger & A. Lebreton, Agroécologie, une transition vers des modes de vie et de développement viables. Paroles d'acteurs, 20-21 (2012)
42. M. Piraux, S. Luciano, D. Paulo & D. Ghislaine, La transition agroecologique comme une innovation socio-territoriale. In ISDA 2010, Cirad-Inra-SupAgro, 9 (2010)
43. Y. Abourabi, Reportage sur l'importance d'adopter l'agroécologie au Maroc. Rev. Intern. Franco., 17 Rue Tiddas, 10010 Rabat, Maroc **(6).** 4-18 (2020)
44. J. Kaur, AK. Prusty, N. Ravisankar, AS. Panwar, M. Shamim, SS. Walia ... & P. Kashyap, Farm typology for planning targeted farming systems interventions for smallholders in Indo-Gangetic Plains of India. Scien. reports, **11(1),** 1-16 (2021)
45. N. Akesbi, D. Benatya, N. El Aoufi, L'agriculture marocaine à l'épreuve de la mondialisation. Econ. Critiq., Rabat, 12-23 (2008)
46. Y. Schoonhoven & H. Runhaar, Conditions for the adoption of agro-ecological farming practices: a holistic framework illustrated with the case of almond farming in Andalusia. Int J Agric Sustain, **16(6),** 442-454 (2018)
47. A. Coulibaly, M. Motelica-Heino & E. Hien, Determinants of Agroecological Practices Adoption in the Sudano-Sahelian Zone. J. Environ. Prot., **10(7),** 900-918 (2019)
48. BJ. Middendorf, A. Faye, G. Middendorf, ZP. Stewart, PK. Jha & PV. Prasad, Smallholder farmer perceptions about the impact of COVID-19 on agriculture and livelihoods in Senegal. Agric. Syst., **190**, 103108 (2021)
49. R. Goswami, K. Roy, S. Dutta, K. Ray, S. Sarkar, K. Brahmachari, ... & K. Majumdar, Multi-faceted impact and outcome of COVID-19 on smallholder agricultural systems: Integrating qualitative research and fuzzy cognitive mapping to ex-plore resilient strategies. Agric. Syst., **189**, 103051 (2021)
50. Deaconu A, Berti PR, Cole DC, Mercille G & Batal M Agroecology and nutritional health: A comparison of agroecologi-cal farmers and their neighbors in the Ecuadorian highlands. Food Policy, **101**, 102034 (2021)
51. P. Tittonell, M. Fernandez, V.E. El Mujtar, P.V. Preiss, S. Sarapura, L. Laborda, ... & I. M. Cardoso, Emerging responses to the COVID-19 crisis from family farming and the agroecology movement in Latin America–A rediscovery of food, farmers and collective action. Agric. Syst., **190**, 103098 (2021)