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Contribution of agricultural research for better resilience of Moroccan agriculture

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Abstract - Agriculture plays a significant socio-economic role in Morocco, representing 13% of the country's Gross Domestic Product and engaging approximately 46% of the population. The strategy of the Green Morocco Plan 2008-2019 has contributed significantly to the Moroccan agriculture by strengthening agricultural sectors, increasing productivity, and enhancing exports. However, climate change, resulting in insufficient rainfall and high temperatures, has reduced the productivity of major crops. Additionally, population growth has led to an increasing demand for agricultural products. Geopolitical factors, such as the conflict in Ukraine, impacting the availability and prices of cereals and oilseeds, have necessitated the development of a more resilient agriculture to secure essential needs in basic agricultural products such as cereals, legumes, meats, fruits, and vegetables. Agricultural research plays a key role in supporting the Generation Green strategy (2020-2030) through various programs aimed at innovative, productive, and resilient agriculture.

This article first presents the general context of food security and sovereignty, followed by tools and solutions to various challenges related to the biodiversity-soil-water nexus, the basis of agricultural productivity and resilience. Genetic resource conservation is crucial for selecting resilient and productive varieties of different crops. Thus, Morocco is strengthening its capacities in this field, with a new gene bank from ICARDA focusing on cereal and legume accessions. A national genetic resources center will be established in 2024 and will include all major crops for Moroccan agriculture. Recently, new wheat varieties have been developed showing yields up to 30% higher than the control variety in drought years. Cochineal resistant varieties of cactus have been selected through a collection of over 300 genotypes and are currently being multiplied for distribution to small-scale farmers. Precision agriculture is a priority for more rational use of inputs, particularly water and fertilizers. The implementation of no-till farming to address drought and soil health issues has been successfully launched since 2020 to cover 1 million hectares by 2030. Finally, the adoption of agroforestry, which contributes to yield improvement through a program of planting multiple crops such as the 100,000-hectare carob tree plantation, is being promoted. All these actions will contribute to the development of a resilient agriculture leading Morocco towards food sovereignty.

Keywords: *agricultural resilience, productivity, sustainability, food sovereignty, food security, climate change*

Contribution de la recherche agricole pour une meilleure résilience de l'agriculture marocaine

Résumé **-** L'agriculture joue un rôle socio-économique important au Maroc. Elle représente 13 % du Produit National Brut du pays et engage environ 46 % de la population. La stratégie du Plan Maroc Vert 2008-2020 a contribué significativement à l'agriculture marocaine à travers le renforcement des filières agricoles, l'augmentation de la productivité et de l'export. Le changement climatique qui engendre une pluviométrie insuffisante et des températures élevées réduit la productivité des principales cultures. De plus l'augmentation de la population engendre une demande croissante en produits agricoles. Avec les autres facteurs géopolitiques comme la guerre en Ukraine, qui a impacté disponibilité et prix des céréales et oléagineuses, le pays est contraint de développer une agriculture plus résiliente pour sécuriser ses besoins essentiels en produits agricoles de base comme les céréales, les légumineuses, les viandes, les fruits et légumes. La recherche agricole joue un rôle clé pour accompagner la stratégie Génération Green (2020-2030) à travers plusieurs programmes visant une agriculture innovatrice, productive et résiliente. Cet article présente d'abord le contexte général de sécurité et souveraineté alimentaire, suivis par les outils et les solutions aux différents défis liés au nexus biodiversité-sol-eau, base de productivité et de résilience.
La conservation des ressources génétiques est primordiale pour la sélection de variétés résilientes et productives des différentes cultures. Ainsi le Maroc renforce ses capacités dans ce domaine, avec une nouvelle banque de gènes de

l'ICARDA focalisant sur les accessions de céréales et légumineuses. Un centre national des ressources génétique verra le jour en 2024 et inclura toutes les cultures importantes pour l'agriculture marocaines. Récemment, des nouvelles variétés de blé ont été développées affichant des rendements jusqu'à 30% supérieurs à la variété témoin en année de sécheresse. Des variétés de cactus résistantes à la cochenille ont été sélectionnées grâce à une collection de plus de 300 génotypes et sont actuellement en multiplication en vue de leur distribution aux petits agriculteurs. L'agriculture de précisions est une priorité pour une utilisation plus raisonnée des intrants en particulier l'eau et les fertilisants. La mise en œuvre du semis direct pour faire face aux problèmes de sècheresse et de santé du sol a été lancée avec succès depuis 2020 pour couvrir 1 M ha d'ici 2030. Enfin, l'adoption de l'agroforesterie qui contribue à l'amélioration des rendements via un programme de plantation de plusieurs cultures comme celui de 100 000 ha de caroubier. Toutes ces actions contribueront au développement d'une agriculture résiliente conduisant le Maroc vers sa souveraineté alimentaire.

Mots clés : *résilience agricole, productivité, durabilité, souveraineté alimentaire, sécurité alimentaire, changement climatique*.

مساهمة البحث الفلاحي في تحسين مرونة الفلاحة المغربية

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ملخص - تلعب الزراعة دورًا اجتماعيًا واقتصاديًا هامًا في المغرب. إنها تمثل 13٪ من الناتج المحلي الإجمالي للبلاد وتشغل حوالي 46٪ من السكان. ساهمت استراتيجية خطة المغرب الأخضر 2008-2020 بشكل كبير في دعم الزراعة المغربية من خلال تعزيز سلاسل الإنتاج الزراعي وزيادة الإنتاجية والصادرات. يقلل التغير المناخي الذي يؤدي إلى نقص في الأمطار وارتفاع درجات الحرارة من إنتاجية المحاصيل الرئيسية. بالإضافة إلى ذلك، يؤدي زيادة السكان إلى زيادة الطلب على المنتجات الزراعية. مع العوامل الجيوسياسية الأخرى مثل الحرب في أوكرانيا، التي أثرت على توفر وأسعار الحبوب والزيوت النباتية، يتعين على البلاد تطوير زراعة أكثر مرونة لضمان احتياجاتها الأساسية من المنتجات الزراعية مثل الحبوب والبقوليات واللحوم والفواكه والخضروات. تلعب البحث الزراعي دورًا رئيسيًا في دعم استراتيجية الجيل الأخضر (2020-2030) من خلال برامج متعددة تهدف إلى دعم زراعة مبتكرة وإنتاجية ومرونة. يقدم هذا المقال أولاً السياق العام للأمن الغذائي والسيادة الغذائية، تليه الأدوات والحلول للتحديات المختلفة المتعلقة بتفاعل التنوع البيولوجي-التربة-المياه، والتي تشكل أساس الإنتاجية والمرونة. إن الحفاظ على الموارد الوراثية أمر بالغ الأهمية لاختيار أصناف مقاومة ومنتجة لمختلف المحاصيل. وبهذا السياق، يعزز المغرب قدراته في هذا المجال، مع إنشاء مصرف جديد للجينات لمنظمة الزراعة والبحوث الدولية (ICARDA)متخصص في الوصول إلى الحبوب والبقوليات. سيتم إنشاء مركز وطني للموارد الوراثية في عام 2024 وسيشمل جميع المحاصيل المهمة للزراعة المغربية. وقد تم تطوير أصناف جديدة من القمح تظهر معدلات إنتاج تصل إلى 30٪ أعلى من الصنف القياسي في سنوات الجفاف. تم اختيار أصناف مقاومة للصدأ في الصبار بفضل مجموعة تتضمن أكثر من 300 نموذج وتجري حاليا عمليات تكاثر لتوزيعها على الفلاحين الصغار. الزراعة المحددة تعد أولوية لاستخدام أكثر منطقية للعناصر المدخلة خاصة الماء والمسمدات. تم إطلاق تنفيذ الزراعة المباشرة لمواجهة مشكلات الجفاف وصحة التربة بنجاح منذ عام 2020 لتغطية 1 مليون هكتار بحلول عام 2030. وأخيرًا، اعتماد زراعة الغابات التي تساهم في تحسين الإنتاجية من خلال برنامج زراعة عدة محاصيل مثل برنامج زراعة 100000 هكتار من شجرة الخروب. ستسهم جميع هذه الإجراءات في تطوير زراعة مرونة تقود المغرب نحو سيادة غذائية.

الكلمات المفتاحية: *المرونة الزراعية، الإنتاجية، الاستدامة، السيادة الغذائية، الأمن الغذائي، تغير المناخ.*

Introduction

As is the case in many countries worldwide, climate change (Balaghi et al., 2024) poses a significant challenge to Moroccan agricultural systems, which face difficult constraints of drought and heat, leading to issues such as low productivity, soil depletion and erosion, and loss of biodiversity. To enhance the resilience of these agroecosystems and ensure sustainable food sovereignty, research can play a crucial role.

Agronomic research can indeed contribute to developing drought- and/or heat-resistant crops and varieties, assist in developing agricultural practices suited to the challenges of climate change, including improved water resource management by identifying high-risk areas for water stress, and studying efficient irrigation systems and strategies, including the reuse of treated wastewater.

Research can also help develop eco-efficient crop management practices more resilient to climate change (Lamaoui et al., 2018), with a focus on promoting agroecology, which employs environmentally friendly and resource-conserving practices.

Furthermore, agronomic research can also aim towards promoting biodiversity conservation by identifying plant and animal resources best suited to changing environmental conditions.

• Definition of Resilience

Resilience in agriculture can be defined as the ability of an agricultural system to absorb shocks and disturbances (related, among other factors, to climatic hazards such as drought, heat, crop diseases, and fluctuations in food prices) and to adapt accordingly (Léa de Oliveira et al., 2019). Resilience in agriculture also implies the ability to maintain sufficient levels of production and productivity to meet the food needs of the population while preserving natural resources and protecting the environment. In other words, resilience in agriculture is the ability to address challenges and adapt to changing conditions while maintaining sustainable and equitable food systems. According to the dictionary of agroecology, three capacities of agricultural systems need to be developed to enhance their resilience to hazards and changes:

- Buffer capacity: the system can tolerate disturbances without deviating from its routine regime. For example, a dairy farm experiencing drought can tolerate this hazard if its forage stocks are sufficient.
- Adaptation capacity: the system can implement technical, organizational, or commercial adaptations to cope with hazards and quickly return to a routine regime. For example, in response to repeated droughts, diversifying crop rotations would distribute climate risks across different crops and increase production stability.
- Transformation capacity: the system can undergo profound transformation to persist. For example, faced with a drastic drop in milk prices, an intensive dairy farm can evolve into an economical and autonomous system, which may involve changing the herd's breed, establishing a new production workshop, or modifying its marketing approach (Léa de Oliveira et al., 2019).

- Definition of Food Sovereignty and Security

Food sovereignty can be defined as the right of peoples to determine and define their own food and agricultural policies, without depending on external aid or large agribusiness corporations. It also involves the protection and preservation of natural resources necessary for food production. Through choices in food consumption as well as agricultural or trade policies, it ensures access to healthy and sustainable food. It is a comprehensive concept where social, economic, political, and environmental aspects are closely intertwined. Indeed, the UN has established a consensus "that every country should be helped to feed itself, and that the issue of food cannot be resolved by concentrating production in the most efficient regions, aid, and international trade" (Dutra, et al. 2020).

Food security, on the other hand, is defined as the situation in which all individuals have access to sufficient, nutritious, and safe food to meet their dietary needs and preserve their health. It relies on four pillars: physical access to food, food availability, food quality, and stability of access to food (FAO, 1997).

- International Context

At the international level, agriculture remains one of the most powerful levers on which countries must act to end extreme poverty, enhance shared prosperity, and feed the 9.7 billion people that the planet will have by 2050, given that agricultural growth has two to four times more effective effects on increasing the income of the poorest populations (World Bank, 2023). However, several factors may jeopardize agriculture's ability to drive growth and reduce poverty, as well as food security.

Following disruptions related to the COVID-19 pandemic, extreme weather events, and geopolitical conflicts (including that between Ukraine and Russia), food systems are exposed to multiple shocks leading to increased food prices and worsening hunger. Agricultural production is further threatened by the increasing effects of climate change, particularly in regions of the world already experiencing food insecurity. Additionally, food systems also contribute to climate change as they account for approximately 30% of global greenhouse gas (GHG) emissions (IAEA, 2023).

It is also worth noting that some current intensive production models often endanger the health of the planet and contribute to unsustainable levels of pollution and waste. One-third of the world's food produced is lost or wasted. It is essential to address this issue if we want to improve food and nutritional security, as well as achieve climate goals and reduce pressures on the environment (World Bank, 2023).

Agriculture in Morocco

Since its Independence, Morocco has placed the agriculture sector at the forefront of its development choices due to the significant economic, social, and territorial challenges it poses. Over the decades, this sector has distinguished itself through its impacts on the national economy, both intrinsically and through its intersectoral interactions. This is particularly reflected in its contribution to the GDP, representing nearly 13%, with variations among regions. Its role is crucial in the development of rural regions (where employment opportunities are limited), as it provides jobs covering nearly 46% of the country's total workforce, and approximately 74% in rural areas (Louali, 2019).

Indeed, despite increasing urbanization, agriculture has a significant multiplier effect upstream and downstream, on the rest of the economy. Its evolution is crucial for the balance of rural society and thus for national stability. It also holds major societal and cultural importance as a guardian of values, know-how, landscapes, and diversity, which constitute the central framework of the country's heritage. Moreover, it plays a primary role in the use and management of natural resources, notably water, which becomes crucial for the country's future development (HCP, 2019).

The Moroccan agricultural sector is highly diversified, with a wide variety of crops, including major crops (cereals, legumes, etc.), fruit trees (citrus, olive, date palm, almond, fig, etc.), horticultural crops (tomato, potato, etc.), aromatic and medicinal plants, not to mention significant animal production (meat, eggs, milk, etc.). Such diversification allows Morocco to contribute to the food needs of its population and export a wide variety of agricultural products to other countries.

To consolidate the strategic role of this sector, a major turning point was taken in 2008 with the launch of the Green Morocco Plan (PMV), which injected new dynamism into the agricultural sector. Over the last decade, the sector has undergone significant structural evolution characterized by the strengthening of high-productivity and value-added agricultural sectors (particularly arboriculture, horticulture, and livestock) and by a significant improvement in its resilience to climate hazards (Morocco Diplomatic, 2022).

The expiration of the PMV in 2020 raised questions about consolidating the achievements recorded by the agricultural sector until then and addressing some of the structural, endogenous, and exogenous challenges it continues to face. These include intersectoral integration of the sector, especially with its agro-industrial downstream, mobilization and efficient use of water resources, enhancing the competitiveness of agri-food products in the global market and repositioning them in high-potential markets, as well as consolidating the inclusive nature of Moroccan agriculture by integrating it into an integrated ecosystem at the rural level (Louali, 2019). These concerns formed the basis of the main ambitions of the new agricultural strategy 'Generation Green 2020-2030'.

Challenges

Despite the progress made during the last decade, Moroccan agriculture still faces numerous interrelated challenges that impact national needs and priorities. Issues such as water scarcity, soil degradation, low productivity, land management, and agricultural policies are at the forefront of concerns that both policymakers and scientists are grappling with to find solutions and integrate them into development strategies.

- ***Water scarcity****:* Water supply is a major challenge for Moroccan agriculture due to the scarcity of water resources in the country. Increasing variability in precipitation and frequent droughts associated with climate change (Balaghi et

al., 2024) have significant impacts on agricultural production and pose important challenges in terms of food security. This leads to a reduction in water availability, negatively affecting agricultural yields, particularly in regions highly exposed to these challenges. For example, cereal productivity was 100 million quintals in 2021 with an average rainfall of 300 mm (World Bank, 2021), whereas it dropped to only 30 million quintals in 2022 with an average rainfall of 200 mm (Direction Générale de la Météorologie, 2023). Drought caused a 70% reduction in cereal productivity between an average year and a drought year. Water resources in Morocco are currently estimated at less than 650 m^3 per capita per year, compared to 2500 m^3 in 1960, and could decrease to below 500 m^3 by 2030 (Bennouna, 2020). According to the Ministry of Agriculture, Morocco is expected to experience a gradual increase in drought conditions until 2050. This is due to a projected drop in rainfall (approximately 10 to 30%) and an increase in temperatures (up to 1.8°C). (Balaghi et al 2024; Driouch et al 2013),

- ***Soil degradation:*** The development of Moroccan agriculture faces the scarcity of natural resources in a context of global changes that accentuate their degradation and loss of biodiversity. Indeed, more than 12.5 million hectares of land are threatened by degradation, a situation exacerbated by the adoption of intensive agricultural practices, which have led to soil erosion, endangering the sustainability of production systems (FAO, 2022; Larbodière et al., 2020). Therefore, the future of Moroccan agriculture requires promoting good practices that can support the resilience of production systems and ensure the transformation of Moroccan agriculture towards an environmentally, economically, and socially sustainable model.

- ***Relatively low productivity:*** Despite the strategic importance of agriculture in Morocco and the significant progress achieved through the Green Morocco Plan, certain constraints still require more attention to achieve better performance. Indeed, the national average productivity remains low, especially in fragile areas with predominantly subsistence agriculture. Moreover, the irregularity of the national average production has become structural, particularly due to the negative effects of climate change and the limited use of modern and efficient agricultural technologies (HCP, 2019). It is within this framework that the new Generation Green strategy aims to improve this situation by increasing Moroccan agricultural productivity by 50% by 2030.

In summary, to address the numerous challenges facing Moroccan agriculture, the government has implemented policies and programs to encourage investment in agriculture, promote sustainability, and improve sector productivity. It is essential to invest in sustainable agricultural technologies and practices, strengthen water resource management, secure land rights, and improve farmers' access to finance, training, and markets.

The Generation Green Strategy 2020-2030

"Generation Green" is the name given to the current Moroccan agricultural strategy for the period 2020-2030. It builds upon the achievements of the Green Morocco Plan (2008-2019), which has delivered remarkable results in terms of growth and sustainability in the agricultural sector. A meticulous evaluation of this plan has been conducted with active contributions from agricultural interprofessions and regional agricultural chambers. Reviewing the accomplishments since 2008, whether in terms of sectors, regions, or cross-cutting projects, has identified areas for improvement and new challenges to overcome, aiming to propel agricultural development to a new level.

As the name suggests, "Generation Green 2020-2030" places human capital at the forefront of its concerns, constituting its primary foundation. Its aim is to contribute to the emergence of a rural middle class, energize rural youth, enhance human capital, and further structure farmers around efficient agricultural organizations. The advancement of human capital is indeed a prerequisite for continuing the modernization of the sector and consolidating its achievements.

The sustainability of agricultural development constitutes the second foundation of the "Generation Green 2020-2030" vision. Closely linked to human capital, this foundation seeks to consolidate the gains of the Green Morocco Plan while making a qualitative and technological leap through specific actions on agricultural sectors, distribution chains, quality and innovation, as well as in terms of natural resource preservation and strengthening sector resilience (Ministry of Agriculture, Maritime Fisheries, Rural Development, and Water and Forests, 2023).

- Biodiversity-Water-Soil Nexus

The concept of the Biodiversity-Water-Soil Nexus refers to the interconnection between biodiversity, water, and soil within an ecosystem. These three components are closely linked, and any change or disruption in one can have significant impacts on the others. For example, changes in land use can lead to soil disturbances, resulting in habitat loss and fragmentation, which can reduce biodiversity and also affect water quality and availability. Similarly, changes in water availability or quality can impact soil health and, ultimately, biodiversity. The purpose of this Nexus concept is to establish synergy between these resources for integrated management to achieve sustainably productive agriculture. Several studies involve other components in this Nexus concept, including energy .

Understanding and managing the Nexus between biodiversity, water, and soil is essential for maintaining healthy and resilient ecosystems. This may involve a range of strategies, including conserving natural habitats, implementing sustainable land management practices, and enacting policies and regulations to protect these vital resources. By recognizing and addressing the links between biodiversity, water, and soil, we can promote sustainable development and ensure the long-term health and productivity of our ecosystems. The concept of conservation agriculture fits

perfectly within this framework as one of the most important and efficient methods for conserving soils and water, offering an interesting and promising alternative to sustainably improve food security, preserve the environment in the long term, and enhance agricultural resilience to climate change (Vankeerberghen and Stassart, 2014).

Contribution of Research to Agricultural Resilience

The contribution of research has historically demonstrated the significant potential to enhance agricultural productivity. One of the most renowned examples is the contribution of research to the Green Revolution. Indeed, through the development of new wheat varieties by Norman Borlaug and his team, combined with factors such as fertilizer use and mechanization, wheat production in India and Pakistan doubled between 1965 and 1970, thus averting famine and bolstering the food sovereignty of both nations.

Within the framework of the Generation Green strategy, research institutions in Morocco, along with other agricultural entities, have set several objectives for innovative, productive, and resilient agriculture. For instance, INRA, in collaboration with other partners, aims to increase the average yield of major crops by 50% by 2030. This increase is achievable through the implementation of a series of measures, some of which are currently underway, with specific examples outlined below.

Crop genetic resources for food and agriculture serve as the raw material for enhancing agricultural productivity and product quality, thereby ensuring food security. The INRA Settat gene bank preserves over 72,000 accessions and is nearing capacity. The new National Center for Genetic Resources, with expanded capacity (up to 200,000 accessions capacity), will become operational in 2024, facilitating the expansion of plant collections. Additionally, it will initiate a national collection of microorganisms and animal breeds, which are also crucial for food security (Sahri et al, 2024).
Cereals, particularly wheat, play a vital role in global food security. For example, in addition to providing 20% of calories and protein to our diets, almost 25% of wheat production is traded internationally. The cereal sector (including soft wheat, durum wheat, and barley) is one of the main agricultural sectors in Morocco. With an average production of 65 million quintals per year, Morocco falls short of food sovereignty concerning this commodity. Therefore, additional efforts are required to develop cereal varieties resistant to diseases, pests, and primarily drought, as 75% of cereal acreage is in arid and semi-arid zones (Amamou, 2024). Among the most drought-resistant cereals are barley (Jilal, 2024) and triticale (El Haddoury et al 2024), with several recently developed varieties undergoing multiplication to improve adaptation to low rainfall. Cereal-legume rotations must be strengthened to contribute to more sustainable and resilient agriculture (Houasli and Abderamane, 2024). Lentils are among the most drought-resistant legumes (Idrisssi et al, 2019; Zeroual et al, 2024).

National production of oilseed crops (excluding olive) accounts for less than 2% of Morocco's needs. Diversification, development, and adoption of resilient oilseed crops can address climate change challenges and improve food sovereignty in edible oils. New varieties of rapeseed with greater resilience have been developed and are currently being multiplied (Nabloussi et al, 2024).

With increasing irrigation, soils are becoming increasingly saline. Adequate management is necessary for soil sustainability. Efforts to minimize the negative consequences of soil salinity include mapping saline-affected soils, adopting appropriate agricultural practices such as improved and precision irrigation, crop rotation, and using salt-tolerant plants (Zouahri and Hallam, 2024). Soil conservation measures, such as proper fertilizer management, organic amendments, and crop residues, can prevent soil salinization and restore damaged agroecosystems.

A program is planned in Morocco to guide the rational use of fertilizers for better crop fertilization and to better understand the fertility status of cultivated soils, thereby improving soil productivity and sustainability (Bouhafa et al, 2024).
To address soil depletion, the development of more sustainable agricultural practices such as no-till farming will contribute to improving the profitability of small farmers through higher yields while enhancing carbon sequestration and soil organic matter levels (Moussadek et al 2024).

Agroforestry has several benefits: soil preservation by reducing erosion, high carbon sequestration, and increased yields with annual crops (El Koudrim et al, 2024). Morocco has committed to planting 100,000 hectares of carob trees (Meziani and Razouk, 2024), 120,000 hectares of cactus (El Aalaoui and Sbaghi, 2024), and 50,000 hectares of argan trees by 2030. In addition to the benefits mentioned below, these three crops are more drought-resistant than other fruit trees (citrus, date palm) and with highly sought products.
Enhancing the resilience of Moroccan agriculture depends on mastering the use of irrigation water. Studies have been conducted on the water needs of major crops, comparing modern and still-dominant traditional irrigation techniques, crop yield responses to various levels of deficit irrigation, irrigation management methods, and the application of irrigation scheduling modeling. Water savings ranging from 15% to 30% compared to conventional techniques have been observed (Bouazzama et al, 2024).

Precision agriculture can address water scarcity challenges. For example, using sensors to measure soil moisture or satellite imagery to track crops. These data can help farmers provide the necessary water for productive crops with greater accuracy (Benabdelouhab et al 2024). In some cases, water savings of up to 30% can be achieved. Several biotechnological tools have been used to assist in the development of resilient varieties including doubled haploids and the use of molecular markers (Elhaddoury and Khouakhi, 2024).

Reducing losses in the value chain is also a form of resilience improvement. Significant losses estimated at up to 30% of production occur during harvest, transportation, and storage of agricultural products before reaching consumers (Boughlala, 2024).

Sheep and goats are a significant part of meat consumption in Morocco. Local populations and the overall genetic diversity of small ruminants can contribute to the resilience of livestock systems. For the nutritional needs of small ruminants, studies have highlighted the diversity of local and/or alternative feed resources in two regions. Data on the chemical composition, digestibility, and nutritional value of these resources are essential for formulating balanced supplementation rations, optimizing animal production, and improving the sustainability and resilience of livestock systems (Benjelloun et al, 2024; Ayadi et al 2024).

Improvements in the resilience of the various products described above will necessarily contribute to the resilience of communities in Morocco (Harrak et al, 2024; Laamari et al, 2024).

Perspectives

Despite the challenges mentioned above, the research programs and actions undertaken within the framework of the Generation Green strategy present an opportunity to find solutions and move towards improved resilience and food sovereignty. To successfully address these challenges, the following elements are essential. The utilization of innovative tools that have shown benefits for crop improvement is paramount. These technologies currently in use include genetic selection from a biodiverse germplasm, genomics, biotechnology, precision agriculture with rationalized fertilization and irrigation, high-throughput phenotyping tools, and speed breeding techniques. The planning of the Generation Green strategy must be implemented with modern and efficient management of various programs, with regular and measurable monitoring. Furthermore, the availability of both human and material resources must be sufficient to achieve the various objectives. Finally, success will be achieved through partnerships with various stakeholders: national and international research institutions, various departments of the ministry, industry, farmers, and their representatives.

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