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Conservation-Oriented Evaluation of Opium Poppy Production Potential in the Republic of North Macedonia Using SWOT and TOWS Approaches

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Abstract

Opium poppy (*Papaver somniferum* L.) has a long tradition in North Macedonia and is internationally recognized for its high quality. Despite this, cultivated areas have steadily declined, reaching only 35 hectares in 2022, with capsule yields of 300 kg ha⁻¹ and seed yields of 583 kg ha⁻¹. The SWOT analysis shows that opium poppy production has several important strengths. The country has favorable agroclimatic conditions, domestic varieties, experienced farmers, and support from government subsidies. The presence of a pharmaceutical buyer is also an important advantage, because it gives this production a clearer market direction. However, there are still many limits that slow down further development. Production is mostly based on small farms, while yields and prices are often low. Many farmers also use outdated machinery, which makes production less efficient. Another problem is the limited interest of buyers and the lack of a secure market for poppy seed. In addition, legal restrictions make the export of capsules more difficult. There are also several opportunities for future growth. The TOWS matrix suggests that the sector could become more competitive through value-added products, stronger cooperation between farmers, modernization of machinery, public information campaigns, and public-private investment. Although opium poppy production faces many challenges, it still has good potential to develop from a declining traditional activity into a sustainable and competitive niche sector, but this requires coordinated institutional support, modernization, market diversification, and the development of value-added products. With better policies and a clearer market strategy, it could develop into a more sustainable and competitive agricultural sector.

Keywords: *Papaver somniferum*; SWOT analyses; TOWS analyses; PESTLE analyses



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1. Introduction

Opium poppy (*Papaver somniferum* L.) is a plant of significant economic, medicinal, and cultural value [1,2]. Cultivated for over 5000 years, it is the source of several pharmacologically important alkaloids, including morphine, codeine, and thebaine, which are essential for the production of legal opioid medications [3,4]. Thebaine is not commonly used directly as a medicine, but it represents an important precursor for the semi-synthesis of several pharmaceutical opioids [5–7]. Other alkaloids, such as papaverine and noscapine,

are associated with vasodilatory and antitussive properties, respectively. Therefore, despite strict legal control and the risk of misuse, opium poppy remains an important crop for the pharmaceutical industry and for the production of essential medicines.

Legal opium production occurs in a few countries under strict government control for legitimate pharmaceutical and food industry use. Such cultivation is used to produce the global supply of more highly processed forms of opium, such as opium tincture and morphine. India was the main producer and exporter of licit raw opium in 2017, accounting for 432.5 tons (47.5 tons in morphine equivalent) or 98.4% of total global licit production. It was followed by China, which produced 6.4 tons (0.7 tons in morphine equivalent) and where poppy straws (dried seedpod capsules) have replaced opium as the main raw material used in the manufacture of alkaloids since 2000. The Democratic People's Republic of Korea also produced smaller amounts of opium, but exclusively for domestic consumption and use [8]. The large producers are also Turkey, Australia, France, Hungary, and Slovakia. Conversely, illicit opium poppy cultivation is concentrated in specific regions, notably the "Golden Crescent" (Afghanistan, Iran, and Pakistan) and the "Golden Triangle" (Myanmar, Laos, and Thailand). Until 2022, Afghanistan, with a sowing area of 224,000 ha, accounted for approximately 80% of global illicit opium production [9]. As of 2023, the cultivated area has been reduced by 95% to only 10,800 ha. Parallel opium production fell to 333 tons (compared to 6200 tons in 2022). In 2023, it is estimated that 24–38 tons of heroin (at 50–70% purity) could be processed from opium (compared to 350–580 tons in 2022) [10]. In addition to opium alkaloids, *Papaver somniferum* is also cultivated for its seeds, which are a legally traded and widely consumed secondary product. Poppy seeds are nutritionally valuable, rich in oil, dietary fiber, essential fatty acids, micronutrients, and antioxidants [11]. Unlike latex, the seeds contain negligible quantities of narcotic alkaloids, making them safe for consumption when properly processed. The legal international trade in poppy seeds is sizable: the European Union alone imports thousands of tons annually, primarily for the food industry (World Integrated Trade Solution). In Macedonia, the first poppy field was planted in 1835 near Shtip, likely introduced from Turkey's Afyon Karahisar province during the period of the Ottoman Empire. Farmers quickly embraced the new crop, locally known as *afion*. Early production records suggest that the region's favorable climate and soil conditions contributed to the development of opium poppy material with recognized quality characteristics. As a result, cultivation spread rapidly to the regions of Kavadarci, Radovich, Strumica, and Gevgelija. By the latter half of the 19th century, Macedonia had already established itself as a major producer of high-quality opium [12].

The more recent data on poppy related to the Republic of North Macedonia indicate that after the First World War, the average area under poppy cultivation was 7605 ha, with a minimum of 2495 ha in 1921 and a maximum of 14,110 ha in 1930. The production of raw opium ranged from 25 tons (in 1922) to 185 tons (in 1928), while seed production ranged from 681 to 2540 tons. After the Second World War (between 1947 and 1960), the average yield of raw opium was 5.9 kg ha⁻¹. During the same period, seed yield varied from 200 to 870 kg ha⁻¹, averaging around 420 kg ha⁻¹. However, under experimental conditions, with the application of proper and timely agronomic practices, yields were significantly higher, ranging from 20 to 30 kg ha⁻¹ of raw opium and 800 to 1200 kg ha⁻¹ of seed. According to the agricultural development plans, by 1965 it was anticipated that the area under poppy cultivation would reach 7500 ha, with a production of 65 tons of raw opium and 4600 tons of seed [13]. In the period that followed, the situation changed drastically. The reduction in poppy-growing areas was largely the result of the prohibition of capsule lancing for raw opium production, together with the replacement of poppy by other crops. In the Republic of North Macedonia, opium poppy cultivation is now subject to strict legal control under the Law on Control of Narcotic Drugs and Psychotropic Substances [14] and the

2023 bylaw jointly adopted by the Ministry of Agriculture, Forestry and Water Economy (MAFWE) and the Ministry of Health [15]. Cultivation is permitted only for persons and institutions who have obtained approval from MAFWE, following the signing of a contract with an authorized buyer and the registration of the cultivation area within 15 days after sowing. For scientific purposes, poppy may be cultivated without prior approval, but with a mandatory prior notification of the cultivation area to MAFWE.

Macedonian poppy populations in the 1800s probably arose from a cross between white-seeded poppy (*Papaver somniferum* var. *album*) and gray-seeded poppy (*Papaver somniferum* var. *griseum*). Both varieties are used in the production, but the white has a greater morphine content. Kusvie [16] described that cultivated poppy in Macedonia had 5–8 capsules per plant. Seeds varied greatly in color, from grayish white to light brown, which was not considered when selecting seeds for sowing. The varieties were yielding 300–400 kg of seed/ha, with a constant morphine content of 15.9–17.2%, 0.7–1.7% thebaine, and 1.2–3.3% papaverine. According to the ratio between papaverine and thebaine content, Macedonian opium belonged to the papaverine type, unlike the majority of the Asian type [12]. Siljanoski [17] analyzed two local Macedonian poppy populations: white-seeded poppy (white flowers, cream seeds) and blue-seeded poppy (dark purple flowers, light to dark blue-gray seeds). Those two populations were used as a genetic resource in the poppy breeding program during the period 1960–1970, resulting in a new variety, Pionir (*Papaver somniferum* ssp. *euroasiaticum* var. *caesium*) created by the team from the Faculty of Agriculture in Skopje. Another breeding program was performed by the company Alkaloid, which resulted in a variety, Alkaloid 1. Starting from 2014, the Faculty of Agricultural Sciences and Food in Skopje has been establishing a seed collection of Macedonian landraces, which currently contains 63 samples. Nearly half of the farmers maintain white-seeded landraces, claiming that the seeds are very old. Although most of the farmers are not cultivating poppy anymore, they have been keeping the seeds in jars in their basements for more than 15 years [12].

The external and internal environmental factors of opium poppy production were the aims of this study. All factors were investigated and determined through a SWOT analysis, on the basis of a TOWS matrix (threats, opportunities, weaknesses, and strengths) that was created, with an aim of connecting all components and formulating a conceptual framework for the development strategy of opium poppy production.

2. Materials and Methods

2.1. Data Sources

The data from the harvest area (ha), average capsules yield (kg/ha), average seed yield (kg/ha), purchased poppy capsules (kg), and total seed production (t) for opium poppy production were taken from the annual report of the ministry of agriculture, forestry and water economy of Republic of North Macedonia [15] and pharmaceutical company Alkaloid AD Skopje [18].

2.2. SWOT Analysis and TOWS Matrix

The investigation activities were realized in 2017 as part of the project Building the Basis for the Reform of the Tobacco Sector in the Republic of North Macedonia (EuropeAid/138538/IH/SER/MK). The SWOT analysis was conducted using qualitative information obtained from semi-structured interviews (Supplementary Materials) with 20 farmers from the Radovish region who currently cultivate or had previously cultivated opium poppy, together with consultations involving studies in agronomy. The interviews followed a common interview guide covering production practices, technical constraints, market conditions, institutional support, future development opportunities, and perceived

risks. Interview notes were coded and grouped into common themes. Factors describing internal characteristics of the production system (e.g., production resources, technical capacity, farmer knowledge) were classified as strengths or weaknesses, whereas external factors (e.g., market conditions, legislation, policy support, environmental conditions, and socio-economic trends) were classified as opportunities or threats.

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SO strategies—use internal strengths to capitalize on external opportunities;

WO strategies—aim to address internal deficiencies by capitalizing on external opportunities;

ST strategies—use strengths to avoid or mitigate the effects of external threats;

WT strategies—defensive methods to mitigate internal flaws and prevent external dangers.

2.3. PESTLE Analysis

In addition to the SWOT analysis matrix, the TOWS matrix, a Political, Economic, Social, Technological, Legal, and Environmental analysis (PESTLE analysis) [21] was conducted to evaluate the broader macro-environmental factors affecting opium poppy production potential in North Macedonia. The identification of PESTLE factors was based on three groups of data sources: official statistical and institutional data, legal and regulatory documents, and expert and farmer-based information collected during the SWOT analysis. Official data included production indicators such as cultivated area, capsule yield, seed yield, purchased poppy capsules, and total seed production for the period 2017–2022. Legal and institutional sources included national legislation regulating opium poppy cultivation, licensing procedures, registration requirements, authorized buyer contracts, and export restrictions. Additional information was obtained from expert assessment and interviews with farmers from the Radovish region who cultivate or have previously cultivated opium poppy.

The PESTLE analysis included six dimensions: political, economic, social, technological, legal, and environmental. Political factors referred to state control, institutional coordination, government subsidies, and the role of public authorities in regulating opium poppy cultivation. Economic factors included production scale, capsule and seed yields, purchase prices, market opportunities, pharmaceutical demand, seed export, and value-

added products such as poppy seed oil. Social factors included cultivation tradition, farmers' knowledge, social perception, farmer reluctance, rural depopulation, and the aging farming population.

Technological factors referred to the level of mechanization, sowing and harvesting practices, agronomic management, possibilities for yield improvement, laboratory analysis of alkaloid content, and Geographic Information System-based monitoring (GIS-based monitoring). Legal factors included national legislation, licensing procedures, contracts with authorized buyers, registration of cultivated areas, and restrictions related to capsule export. Environmental factors included agroclimatic suitability, soil and water protection, crop rotation, erosion risk, pesticide use, climate extremes, and the need to avoid environmentally sensitive areas.

The identified factors were organized in a PESTLE matrix and interpreted together with the SWOT analysis and TOWS matrix results. This enabled a more comprehensive conservation-oriented evaluation of the production potential of opium poppy in North Macedonia.

3. Results

3.1. Production Trends

Based on the obtained data, opium poppy was cultivated on an average area of 36 hectares during the period 2017–2022. The average capsule yield was 237 kg ha^{−1}, ranging from a minimum of 101 kg ha^{−1} in 2017 to a maximum of 300 kg ha^{−1} in 2022. The average seed yield over the entire analyzed period was 592 kg ha^{−1}, with annual values ranging from 427 kg ha^{−1} in 2017 to 667 kg ha^{−1} in 2020 (Table 1).

Table 1. Opium poppy production in the Republic of Macedonia, period 2017–2022.

Year	Harvest Area (ha)	Capsule Yield (kg ha ^{−1})	Seed Yield (kg ha ^{−1})	Purchased Poppy Capsules (kg)	Total Seed Production (t)
2017	59	101	427	6260	25
2018	41	132	635	5398	26
2019	15	236	611	3536	9
2020	24	363	667	8705	16
2021	42	290	627	12,180	26
2022	35	300	583	10,500	20
Average	36	237	592	7763	20.3

3.2. The SWOT Analysis of Opium Poppy Production in RN Macedonia

The SWOT analysis (Figure 1) of opium poppy cultivation. It shows the good and bad sides of production, as well as future chances and risks.

Strengths are the positive internal factors. There is a long tradition of poppy cultivation, and farmers already have knowledge about growing this crop. The climate and soil are good, and there are local varieties for planting. The poppy also has a high morphine content, which makes it valuable. Production is supported by subsidies, and the pharmaceutical company Alkaloid AD buys the product.

Weaknesses are the internal problems. The cultivated areas are small, and sowing and harvesting are mostly done manually. Yields of capsules and seeds are low, and the purchase price is not high enough. Also, farming methods are outdated, and there is no stable industry for buying and processing seeds. The pharmaceutical industry does not show a strong interest in expanding production.

Opportunities are external possibilities for development. There is potential to export poppy seeds and produce poppy seed oil. Small oil-processing units could be developed.

International cooperation with foreign companies could also help production and research. Poppy can also be grown as a spring crop.



Figure 1. A SWOT (Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T)) analysis of opium poppy production in RN Macedonia.

Threats are external risks. There is a risk of misuse of the crop because the poppy is a sensitive and controversial plant. Some farmers may not want to grow it. Other problems are market instability, abandonment of agricultural land, and an aging farmer population.

In short, poppy cultivation has good natural conditions, tradition, and experience, but production remains small, old-fashioned, and affected by market and social risks.

3.3. The TOWS Analysis of Opium Poppy Production in RN Macedonia

Based on a SWOT analysis, a TOWS matrix was developed, in which the components were connected according to the four possible strategies as shown in Figure 2. A TOWS connects the main points from the SWOT analysis and shows possible strategies for future development. Instead of only listing advantages and problems, it explains how the sector can use its positive sides, reduce its weaknesses, and react to outside risks.

The first strategy is to use the strong background of poppy production to create new market opportunities. Since the country already has experience, suitable natural conditions, and recognized quality, production could be better connected with foreign partners, research institutions, and new buyers. This could help develop seed export and poppy seed oil production.

The second strategy is to improve the production system. Traditional knowledge is useful, but it should be combined with modern technology. Better sowing methods, improved harvesting, and more efficient agronomic practices could increase yields and make production more profitable for farmers.

The third strategy is to create stronger links between farmers, processors, and industry. A more organized purchasing and processing system could make the market safer and more predictable. Small oil-processing units could also give farmers an extra source of income and reduce dependence on only one buyer.

The fourth strategy is to reduce risks connected with the sensitive nature of the crop. Clear control, legal production, and cooperation with trusted companies are important. This could make farmers feel safer and reduce negative opinions about growing poppy.

Finally, the TOWS analysis shows that the future of poppy cultivation depends on modernization, better organization, and market development. The crop has potential, but it needs stronger support, safer market conditions, and more interest from younger farmers.

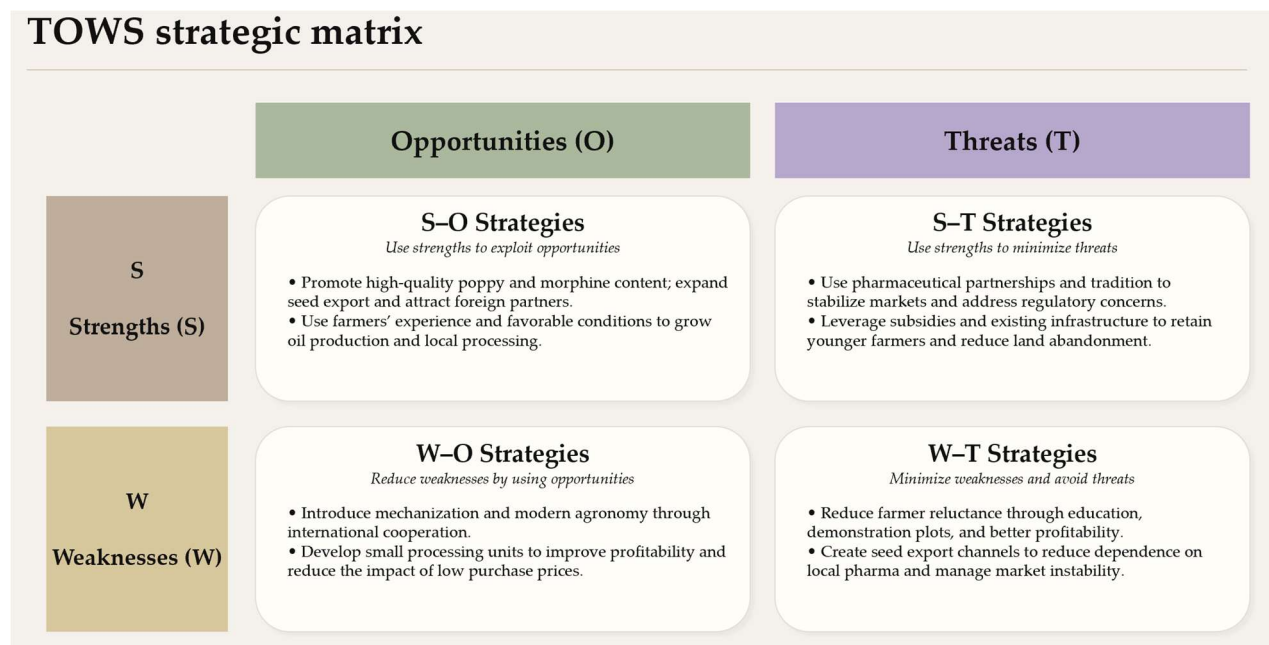


Figure 2. A TOWS matrix of opium poppy production in RN Macedonia.

Considering the current production system and institutional framework, the proposed strategies can be prioritized according to their implementation timeframe. Short-term priorities include improving cooperation between farmers and the pharmaceutical industry, strengthening extension services, promoting certified seed use, and modernizing existing production practices through better agronomic management and mechanization. Medium-to long-term strategies include developing value-added products such as poppy seed oil, establishing local processing facilities, strengthening international research cooperation, diversifying export markets, and implementing breeding programs aimed at improving yield potential and quality. Such prioritization reflects the current industrial capacity and provides a realistic pathway for gradual sector development.

3.4. The PESTLE Analysis of Opium Poppy Production in RN Macedonia

The PESTLE analysis (Figure 3) indicates that the revitalization of opium poppy production in North Macedonia depends on the interaction of several macro-environmental factors. Politically and legally, the sector requires strong state control, transparent licensing procedures, and coordination among relevant institutions. This is particularly important because opium poppy is a sensitive crop with potential risks of misuse. At the same time, the existence of subsidies, domestic pharmaceutical demand, and traditional production knowledge provides a foundation for controlled sector development.

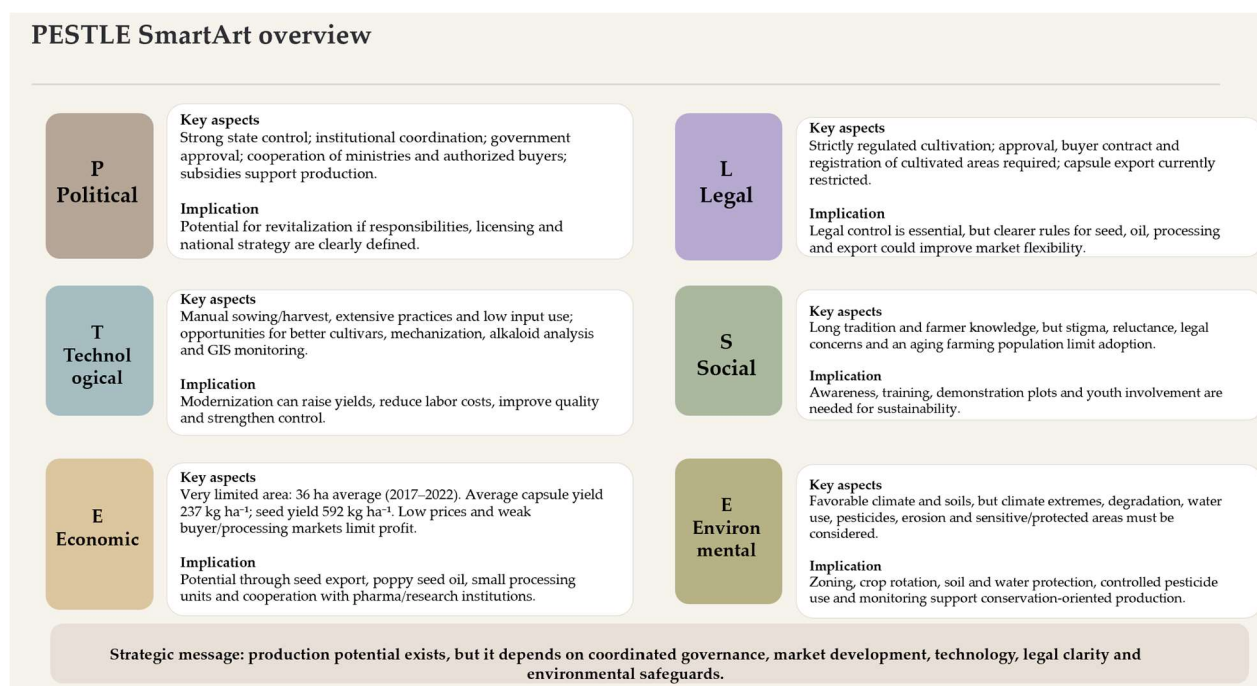


Figure 3. PESTLE analysis of opium poppy production.

4. Discussion

4.1. Production Performance and Agronomic Constraints

Several scientific studies have evaluated capsule and seed yields in *Papaver somniferum* under varying environmental and agronomic conditions. Kara [22], in a two-season study conducted in Turkey, reported capsule yields ranging from 204 to 1375 kg ha⁻¹ and seed yields between 286 and 1520 kg ha⁻¹, depending on the sowing season and cultivar. Similarly, Yazıcı et al. [23], in a study conducted under Tokat conditions in Turkey, reported capsule yields ranging from 1035 to 1566 kg ha⁻¹, while seed yields ranged from 1229 to 1997 kg ha⁻¹. In a later study, Yazıcı [24] examined autumn and spring sowing in different opium poppy genotypes and showed that autumn sowing generally resulted in higher productivity, with capsule yields of 1156–2393 kg ha⁻¹ and seed yields of 1162–2420 kg ha⁻¹. Compared with these results, the data in Table 1 show much lower average yields in North Macedonia, with capsule yield reaching only 237 kg ha⁻¹ and seed yield 592 kg ha⁻¹. This difference suggests that there is still considerable room for improving production, particularly through the use of more productive cultivars, better choice of sowing time, and improved agronomic practices. The low capsule and seed yields recorded in North Macedonia therefore seem to reflect limitations of the current production system, especially in terms of technology and crop management, rather than the biological potential of the crop itself. Besides cultivar selection, sowing date and sowing rate are also important factors influencing poppy productivity. In a culinary poppy, Neugschwandtner [1] found that the highest seed yields of winter poppy under Pannonian climate conditions were achieved with sowing in early October, while both very early and late sowing reduced yield performance. This confirms that optimization of sowing time should be considered one of the first practical measures for improving poppy production in North Macedonia. Furthermore, nitrogen fertilization management is also very important for successful poppy production, as split nitrogen application has been shown to improve poppy seed yield compared with a single nitrogen application [25]. Therefore, future field trials should include different sowing dates, sowing rates, and fertilization regimes, especially under local agroclimatic conditions.

4.2. SWOT-Based Assessment of Opium Poppy Production

The Republic of North Macedonia has a long-standing tradition in opium poppy cultivation, with proven expertise passed down through generations. The country is recognized for producing one of the top three highest-quality poppies globally, particularly in terms of morphine content. A domestic pharmaceutical company purchases and processes poppy capsules, which gives growers a relatively secure market. The country also has a suitable climate and soil conditions, local varieties, experienced farmers, and government support through subsidies. The weaknesses identified in the present study help explain why current yields in North Macedonia remain much lower than those reported in studies from Turkey and other poppy-growing regions. Rather than reflecting poor crop potential, these limitations suggest that the main constraints are technological, organizational, and market-related. Manual sowing and harvesting, extensive agronomic practices, and weak processing infrastructure reduce production efficiency and discourage farmers from maintaining the crop. This finding is consistent with studies showing that sowing time, cultivar choice, fertilization, irrigation, and improved crop management can substantially increase capsule and seed yields in opium poppy. Furthermore, the main pharmaceutical company shows limited interest in scaling up production, and there is currently no option for exporting capsules, which limits market potential. The opportunities identified by the SWOT analysis should therefore be viewed as mechanisms for reducing dependence on a narrow capsule-based value chain. Development of poppy seed export, edible oil production, and small-scale processing could increase farm-level profitability and make cultivation more attractive, especially where capsule purchase prices are insufficient. In addition, international cooperation may provide access to improved germplasm, quality-control protocols, and research networks, which are essential for a crop that is simultaneously agricultural, pharmaceutical, and legally regulated. The possibility of spring cultivation is also relevant under changing climatic conditions, but it should be tested through field trials before being recommended on a wider scale. Considering the changing climate and agronomic conditions, there is also potential for cultivating poppy as a spring crop, which could better suit farmers' calendars and reduce pressure on autumn plantings. Key threats include the risk of misuse of opium poppy for illegal purposes, which may deter stakeholders and attract regulatory scrutiny. There is a notable reluctance among farmers to grow a controversial crop, often due to social stigma and legal concerns. The sector also faces market instability, with inconsistent demand and pricing. In addition, more farmland is being abandoned, and the farming population is getting older, posing a long-term threat to the sustainability of opium poppy cultivation.

4.3. Comparison with the Turkish Production Model

A useful benchmark for identifying future development opportunities is provided by the Turkish opium poppy production system, which represents one of the world's most successful examples of legally regulated cultivation integrated with pharmaceutical processing. Both Turkey and North Macedonia cultivate opium poppy under strict governmental licensing and in accordance with the United Nations Single Convention on Narcotic Drugs. However, Turkey has established a considerably more integrated production system that combines certified cultivar development, mechanized crop management, centralized purchasing, pharmaceutical alkaloid processing, and diversified utilization of poppy seed for food products and edible oil. Continuous breeding programs have resulted in improved cultivars with high alkaloid content, superior yield potential, and improved adaptation to diverse agroecological conditions, while widespread use of certified seed contributes to stable production and quality standards [26,27]. Furthermore, extensive mechanization has substantially reduced labor requirements and production costs compared with predom-

inantly manual production systems. Another important feature of the Turkish model is the close integration of farmers, research institutions, government agencies, and the pharmaceutical industry through coordinated contractual production and centralized quality control, ensuring stable markets and product traceability. Although direct replication of the Turkish production system is not feasible because of differences in production scale, market size, and institutional capacity, several elements appear highly transferable to North Macedonian conditions. These include strengthening national breeding programmes, increasing mechanization, improving cooperation between producers and processors, expanding value-added processing of poppy seed, and further modernizing regulatory monitoring and traceability systems. Gradual implementation of these measures could significantly improve productivity, farmer profitability, pharmaceutical competitiveness, and the long-term sustainability of legally regulated opium poppy production in North Macedonia.

4.4. Strategic Implications of the TOWS Matrix

According to the TOWS matrix, by aligning internal strengths with external opportunities, several proactive strategies emerge, such as leveraging the country's high morphine content and cultivation tradition to expand seed exports, attract international research partnerships, and promote small-scale oil processing units.

Equally important are the defensive strategies, which aim to use existing strengths to mitigate threats. These include countering farmer reluctance and market instability through institutional support, better contracting models, and regulated supply chains emphasizing the value of natural morphine.

Addressing weaknesses through opportunities is a key part of the matrix, particularly by focusing on improving yields, reducing manual labor, and diversifying market outlets through export and value-added processing. Furthermore, minimizing weaknesses while responding to threats is critical for long-term sustainability. This includes combating low profitability and an aging farmer population with modernization efforts and incentive schemes.

Building on these insights, several steps are proposed: develop a national strategy for poppy revitalization between the Ministry of Agriculture, Forestry and Water Economy, Ministry of Health [15], and private stakeholders to set clear targets for expanding cultivation, improving value chains, and enabling safe and legal export; support research and breeding programs to increase yield, disease resistance, and adaptability; modernize production techniques through training and subsidized equipment; and educate younger generations of farmers to secure long-term adoption. These actions directly operationalize the TOWS-based strategies into practical interventions for sustainable sector growth.

Overall, the TOWS matrix highlights that with targeted investment, regulatory clarity, and market diversification, opium poppy can evolve from a traditional crop into a modern, niche agricultural sector with both economic and scientific value for the Republic of North Macedonia.

From an economic perspective, the current production scale remains very limited, while yields are considerably lower than those reported in comparable studies. This suggests that production potential exists, but it is constrained by low profitability, outdated practices, limited processing capacity, and dependence on a narrow market structure. Therefore, future development should not rely only on capsule production, but should also include value-added products such as poppy seed oil and legally traded poppy seed.

Social and technological factors are also highly important. Although farmers have experience and the crop has a strong historical background in the country, reluctance to cultivate a controversial plant and the aging rural population represent significant barriers. These limitations could be addressed through additional farmer training, demonstration

fields, and support for younger producers. In parallel, technological improvements such as mechanized sowing, GIS-based monitoring, and laboratory quality control could improve both production and regulatory safety.

Environmental and regulatory aspects of poppy production in the Republic of North Macedonia are especially important because opium poppy is both an agricultural and a pharmaceutical crop. Water availability and climate extremes may strongly affect growth, development, and yield, as shown by studies on water stress and irrigation effects in poppy [28–30]. For this reason, any future expansion of cultivation should be based on spatial zoning, soil and water conservation, controlled input use, and avoidance of environmentally sensitive areas. At the same time, the pharmaceutical value of opium poppy is related to its alkaloid profile, particularly morphine and codeine biosynthesis [31]. This justifies the need for strict licensing, laboratory alkaloid analysis, and traceability within the legal production chain. Therefore, the revitalization of opium poppy production in North Macedonia should combine agronomic modernization with strong institutional control and conservation-oriented planning.

In this study, PESTLE particularly extends the SWOT/TOWS framework by highlighting that revitalization of opium poppy production cannot depend only on favorable agro-climatic conditions, tradition, or market opportunities. It also requires coordinated political support, clear legal procedures, technological modernization, social acceptance among farmers, and environmental safeguards. Therefore, PESTLE validates the SWOT/TOWS findings, but also adds an implementation-oriented perspective by identifying the wider conditions that may enable or limit the proposed development strategies.

In this manuscript, the term conservation-oriented refers to the preservation and sustainable use of local Macedonian poppy genetic resources and the traditional agricultural knowledge associated with their cultivation and seed maintenance. These landraces represent valuable genetic material for future breeding, while farmers' long-term seed preservation practices reflect an important component of regional agricultural heritage. Therefore, conservation in this context includes both *ex situ* seed collection and on-farm documentation and maintenance of local poppy diversity.

Future revitalization should also be approached cautiously from environmental and market perspectives. Climate extremes, particularly drought and high temperatures, may increasingly affect poppy growth, capsule formation, seed yield, and alkaloid quality; therefore, adaptation measures such as appropriate sowing dates, drought-tolerant local material, soil moisture conservation, crop rotation, and careful site selection should be considered. At the same time, market diversification through poppy seeds and poppy seed oil represents a possible opportunity, but it requires additional analysis of import demand, competing suppliers, quality standards, certification, and market access conditions. Thus, the present study should be viewed as a strategic starting point for legal and sustainable sector revitalization, while more detailed agronomic, environmental, and market studies are needed in the next research phase.

Finally, the environmental dimension is essential for a conservation-oriented evaluation. Since the study aims to assess production potential from a sustainability perspective, future expansion should be based on careful spatial planning, avoidance of environmentally sensitive areas, soil and water protection, crop rotation, and controlled use of agrochemicals. In this context, PESTLE analysis supports the SWOT and TOWS findings by showing that opium poppy production's long-term revitalization is possible only through an integrated approach combining economic development, legal control, technological modernization, and environmental protection.

4.5. Integrated SWOT–TOWS–PESTLE Analysis

The combined application of SWOT, TOWS and PESTLE analyses provided a comprehensive assessment of the development potential of opium poppy production in North Macedonia. While the SWOT analysis identified the principal internal strengths and weaknesses together with external opportunities and threats, the PESTLE framework explained the broader political, economic, technological, legal, social and environmental conditions that shape these factors.

Political and legal factors strongly influence the sector because opium poppy production is subject to strict licensing procedures, government supervision and contractual obligations with authorized buyers. Although these regulations ensure production control and traceability, they also limit production flexibility and export opportunities. Economically, the relatively small production area, low profitability and dependence on a single pharmaceutical buyer reduce producers' willingness to expand cultivation despite favorable natural conditions and long production tradition.

Technological factors explain several weaknesses identified in the SWOT analysis, particularly outdated mechanization, limited modernization and insufficient processing capacity. At the same time, technological improvements represent one of the main opportunities identified in the TOWS matrix for increasing productivity and competitiveness. Social factors, including an aging farming population, declining interest among younger farmers and the sensitive public perception of opium poppy cultivation, further constrain future sector development. Environmental factors, including favorable agroclimatic conditions but increasing climate variability, simultaneously represent both production advantages and emerging risks.

Consequently, the TOWS strategies should not be considered independently of the broader macro-environment. Their successful implementation depends on supportive agricultural policies, investment in modernization, improved cooperation between farmers, industry and public institutions, and continued compliance with national and international regulatory requirements. The integrated use of SWOT, TOWS and PESTLE therefore provides a more comprehensive strategic framework than any individual analytical tool alone.

4.6. Study Limitations and Future Perspectives

Although the present study did not apply quantitative weighting of SWOT factors, the proposed strategies can be qualitatively prioritized according to their expected urgency, implementation feasibility, and contribution to sector development under current industrial conditions in North Macedonia. The highest short-term priorities (1–3 years) should be given to interventions that can be implemented within the existing institutional and legislative framework while requiring relatively limited financial investment. These include: modernization of sowing and harvesting through subsidized mechanization; improvement of agronomic practices, particularly optimized sowing dates, fertilization, irrigation, and crop management; strengthening agricultural advisory and extension services; expansion of farmer education and training programs; development of contractual production schemes between producers and the pharmaceutical industry; strengthening traceability and regulatory monitoring of licensed production; and promotion of poppy seed marketing and domestic utilization. The second, medium term priorities (3–7 years) involves structural improvements requiring greater institutional coordination and financial investment through: establishment of national breeding programs aimed at developing high-yielding domestic cultivars with improved alkaloid content; development of certified seed production systems; establishment of small-scale facilities for processing poppy seed into edible oil and other value-added products; strengthening cooperation among farmers, research institutions, pharmaceutical companies, and governmental agencies; expansion of inter-

national scientific collaboration; and improvement of export capacity for poppy seed and processed products. These measures would enhance productivity, increase farm income, diversify production, and improve competitiveness within regional and international markets. Long-term priorities (beyond 7 years) should focus on establishing a comprehensive and sustainable opium poppy production system fully integrated into national agricultural and pharmaceutical development policies. These actions include: implementation of a National Strategy for Sustainable Opium Poppy Production; development of integrated value chains linking breeding, production, processing, pharmaceutical utilization, and export; establishment of digital monitoring and traceability systems; increased investment in research infrastructure, biotechnology, precision agriculture, and climate-resilient production technologies; promotion of younger farmers through targeted incentive programs; as well continuous adaptation of legislation to international pharmaceutical standards and market requirements. Successful implementation of these long-term measures would contribute to increased competitiveness of the pharmaceutical sector, higher rural incomes, improved export potential, and sustainable conservation of North Macedonia's long tradition of legal opium poppy cultivation.

5. Conclusions

The SWOT and TOWS analyses clearly show that the Republic of North Macedonia possesses a strong foundation for revitalizing its opium poppy sector, built on tradition, proven quality (in terms of morphine content), and supportive infrastructure. However, outdated practices, low profitability, and an aging farming population threaten its long-term viability. At the same time, some threats should be considered. The possible misuse of the crop creates social stigma and a negative public image. The aging farming population is another serious issue, because fewer young people are interested in this type of production. Market prices can also change quickly, and climate extremes may create additional risks for farmers. By strategically combining internal strengths with emerging opportunities such as seed export, small-scale processing, and international cooperation, the sector can move toward modernization and sustainable growth. Poppy seed oil production could be developed, and seed exports could be expanded. Small processing units could help farmers achieve better value for their products. Participation in international research projects could also improve knowledge and introduce new production solutions. Spring cultivation may offer more flexibility, especially because local farmers already have experience and tradition in growing this crop.

At the same time, defensive measures are required to address farmer reluctance, market instability, and regulatory concerns. A coordinated national strategy that integrates government institutions, research programs, and private stakeholders is essential. This strategy should focus on mechanization, improved agronomy, training for younger farmers, and the creation of new value chains for seeds and oil products. With targeted investment, clear regulations, and stronger market diversification, opium poppy production can transition from a shrinking traditional crop into a competitive, high-value niche sector, providing both economic benefits and scientific opportunities for the country.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/conservation6030086/s1>, S1: Questionnaire for SWOT Analysis of Opium Poppy Production in the Republic of North Macedonia.

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Informed Consent Statement: Verbal informed consent was obtained from all participants before the interviews commenced. Prior to each interview, participants were informed about the purpose of the study, the voluntary nature of their participation, and that the information provided would be treated anonymously and used solely for research purposes.

Data Availability Statement: All data are contained in the manuscript.

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References

1. Neugschwandtner, R.W.; Dobos, G.; Wagentristsl, H.; Lošák, T.; Klimek-Kopyra, A.; Kaul, H.-P. Yield and yield components of winter poppy (*Papaver somniferum* L.) are affected by sowing date and sowing rate under Pannonian climate conditions. *Agriculture* **2023**, *13*, 997. [CrossRef]
2. Varga, I.; Moslavac, T.; Flanjak, I.; Iljkić, D.; Pospišil, M.; Lončarić, Z.; Antunović, M. White-Seeded Culinary Poppy (*Papaver somniferum* L.) Se Biofortification: Oil Quality, Fatty Acid Profile, and Seed Yield. *Plants* **2025**, *14*, 95. [CrossRef] [PubMed]
3. Salavert, A.; Zazzo, A.; Martin, L.; Antolin, F.; Gauthier, C.; Thil, F.; Tombret, O.; Bouby, L.; Manen, C.; Mineo, M.; et al. Direct dating reveals the early history of opium poppy in western Europe. *Sci. Rep.* **2020**, *10*, 20263. [CrossRef] [PubMed]
4. Hong, U.V.T.; Tamiru-Oli, M.; Hurgobin, B.; Okey, C.R.; Abreu, A.R.; Lewsey, M.G. Insights into opium poppy (*Papaver* spp.) genetic diversity from genotyping-by-sequencing analyses. *Sci. Rep.* **2022**, *12*, 111. [CrossRef] [PubMed]
5. Gupcsó, K.; Kókai, Z.; Bálint, M.; Tavaszi-Sárosi, S.; Németh, É.Z. Studies on sensory and phytochemical characteristics of poppy (*Papaver somniferum* L.) varieties for their oil utilisation. *Foods* **2023**, *12*, 3165. [CrossRef] [PubMed]
6. Beaudoin, G.A.W.; Facchini, P.J. Benzylisoquinoline alkaloid biosynthesis in opium poppy. *Planta* **2014**, *240*, 19–32. [CrossRef] [PubMed]
7. Luhmer, K.; Schulze-Kaysers, N.; Feuereisen, M.; Wirth, L.; Maretzky, F.; Wüst, M.; Blum, H.; Dörr, E.; Pude, R. Fatty acid composition, tocopherols, volatile compounds, and sensory evaluation of low morphine yielding varieties of poppy (*Papaver somniferum* L.) seeds and oils. *J. Agric. Food Chem.* **2021**, *69*, 3439–3451. [CrossRef] [PubMed]
8. International Narcotic Control Board. Chapter III: Analyses of the world situation. In *Annual Report 2019*; International Narcotic Control Board: Vienna, Austria, 2019; pp. 55–109.
9. United Nations Office on Drugs and Crime. *World Drug Report 2020*; United Nations Office on Drugs and Crime: Vienna, Austria, 2020; pp. 1–62.
10. United Nations Office on Drugs and Crime. *Annual Report 2023*; United Nations Office on Drugs and Crime: Vienna, Austria, 2023; pp. 1–37.
11. Muhammad, A.; Akhtar, A.; Aslam, S.; Khan, R.S.; Ahmed, Z.; Khalid, N. Review on physicochemical, medicinal and nutraceutical properties of poppy seeds: A potential functional food ingredient. *Funct. Foods Health Dis.* **2021**, *11*, 522–547. [CrossRef]
12. Ivanovska, S.; Jankulovska, M. The story of Macedonian Black Gold—Opium poppy (*Papaver somniferum*). *Landraces* **2019**, *4*, 15–18.
13. Gjorgjevski, J. *Industrijski Kulturi*; Univerzitet vo Skopje: Skopje, North Macedonia, 1964; pp. 157–189.
14. Official Gazette of the Republic of Macedonia. *Official Gazette of the Republic of Macedonia* No. 103; Official Gazette of the Republic of Macedonia: Skopje, North Macedonia, 2008; Volume LXIV.
15. Ministry of Agriculture, Forestry and Water Economy of RN Macedonia. *Annual Report for 2022*; Ministry of Agriculture, Forestry and Water Economy of RN Macedonia: Skopje, North Macedonia, 2023.
16. Kusvie, V. Cultivation of the opium poppy and opium production in Yugoslavia. *Bull. Narc.* **1960**, *12*, 5–13.

17. Siljanoski, J. Productive and Quality Traits of Some Domestic and Foreign Poppy Varieties and Lines in Strumica Growing Conditions. Master's Thesis, Faculty of Agriculture, Skopje, North Macedonia, 2001; p. 47.
18. Alkaloid AD Skopje. Available online: <https://alkaloid.com.mk/> (accessed on 15 May 2026).
19. Ranogajec, L.; Antunovic, M.; Stipesevic, B.; Varga, I. A current status and production potential of industrial hemp in Croatia based on a SWOT analyses. *Poljoprivreda* **2024**, *30*, 56–63. [[CrossRef](#)]
20. Maity, R.; Sudhakar, K.; Razak, A.A.; Karthick, A.; Barbulescu, D. Agrivoltaic: A Strategic Assesment Using SWOT and TOWS matrix. *Energies* **2023**, *16*, 3313. [[CrossRef](#)]
21. Johnson, G.; Scholes, K.; Whittington, R. *Exploring Corporate Strategy*, 8th ed.; Prentice Hall: London, UK, 2007.
22. Kara, N. The effects of autumn and spring sowing on yield, oil and morphine contents in the Turkish poppy (*Papaver somniferum* L.) cultivars. *Turk. J. Field Crops* **2017**, *22*, 39–46. [[CrossRef](#)]
23. Yazici, L. Influence of different sowing times on yield and biochemical characteristics of different opium poppy (*Papaver somniferum* L.) genotypes. *J. King Saud. Univ. Sci.* **2022**, *34*, 102337. [[CrossRef](#)]
24. Yazici, L.; Yilmaz, G.; Ozyilmaz, B.; Gokalp, S. Determination of yield and alkaloids properties of some poppy (*Papaver somniferum* L.) cultivars under Tokat conditions. *J. Agric. Sci.* **2020**, *4*, 693–703. [[CrossRef](#)]
25. Lošák, T.; Richter, R. Split nitrogen doses and their efficiency in poppy (*Papaver somniferum* L.) nutrition. *Plant Soil Environ.* **2004**, *50*, 484–488. [[CrossRef](#)]
26. Gümüşçü, A.; Arslan, N.; Sarıhan, E.O. Evaluation of selected poppy (*Papaver somniferum* L.) lines by their morphine and other alkaloid contents. *Eur. Food Res. Technol.* **2008**, *226*, 1213–1220. [[CrossRef](#)]
27. Toprak Mahsulleri Ofisi (TMO). 86. *Hesap Dönemi Faaliyet Raporu 2023*; Toprak Mahsulleri Ofisi Genel Müdürlüğü: Ankara, Türkiye, 2024.
28. Mahdavi-Damghani, A.; Kamkar, B.; Al-Ahmadi, M.J.; Testi, L.; Muñoz-Ledesma, F.J.; Villalobos, F.J. Water stress effects on growth, development and yield of opium poppy (*Papaver somniferum* L.). *Agric. Water Manag.* **2010**, *97*, 1582–1590. [[CrossRef](#)]
29. Chung, B. The effect of irrigation on the growth and yield components of poppies (*Papaver somniferum* L.). *J. Agric. Sci.* **1987**, *108*, 389–394. [[CrossRef](#)]
30. Stranska, I.; Skalicky, M.; Novak, J.; Matyasova, E.; Hejnak, V. Analysis of selected poppy (*Papaver somniferum* L.) cultivars: Pharmaceutically important alkaloids. *Ind. Crops Prod.* **2013**, *41*, 120–126. [[CrossRef](#)]
31. Hagel, J.M.; Beaudoin, G.A.W.; Fossati, E.; Ekins, A.; Martin, V.J.J.; Facchini, P.J. Morphine biosynthesis in opium poppy involves two cell types: Sieve elements and laticifers. *Plant Cell* **2013**, *25*, 4110–4122. [[CrossRef](#)] [[PubMed](#)]

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