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Research Article

Transforming date palm waste into sustainable opportunities: A SWOT analysis with stakeholder insights

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ABSTRACT- Each year, a substantial amount of leftover date palm material accumulates near date palm plantations in Khuzestan province, southwest Iran. This not only contributes to environmental pollution but also lacks economic benefits. To address this issue, this research explores strategies for utilizing date palm waste, incorporating insights from experts and date palm growers through a survey-based study. The study involved 91 experts from the Agricultural Jihad Organization and the Cooperative, Labor, and Social Welfare General Office, nine faculty members from the Date and Tropical Fruit Research Institute, and 30 members of the growers' cooperative. Data was collected using a questionnaire structured around SWOT analysis, categorizing factors into environmental, social, and economic aspects. The Analytical Hierarchy Process (AHP) method was used to determine weighting, and the data was analyzed with SPSS, Excel, and Expert Choice software. The cumulative score of internal factors (2.685) indicated that strengths outweighed weaknesses, while the total score of external factors (2.52) showed that opportunities were more significant than external threats. Results from the internal and external matrix (IEM) analyses further emphasized the prioritization of invasive strategies. Among these, the key invasive strategies—categorized into environmental, social, and economic aspects—include establishing agricultural cooperatives to purchase palm waste and creating added value. This approach also leverages resources from local universities and research institutes, a skilled workforce in processing and supplementary industries, and the production of animal feed from palm leaves through shredding and supplementation.

INTRODUCTION

The *Phoenix dactylifera*, commonly known as the date palm tree, is a vital fruit-bearing species that thrives in tropical, subtropical, and arid regions, particularly in the Middle East and North Africa. Globally, there are approximately 120 million date palm trees, each producing around 20 kilograms of dried leaves annually, making them the largest source of lignocellulosic dry waste (Tahir et al., 2020). In addition to this, unmarketable dates and other by-products contribute to a substantial volume of organic waste. While this waste has the potential to cause environmental pollution, it also presents an economic opportunity for palm growers (Ahmadi et al., 2020). Beyond fruit production, date palms generate various by-products that are often overlooked and considered waste. For instance, the annual pruning of date palm trees involves cutting 10 to 30 new leaves per tree, generating approximately 35 kilograms of organic waste per tree. Despite traditional waste management practices, a significant portion of this biomass is either burned or abandoned, exacerbating environmental concerns (Abbasi et al., 2020). Proper utilization of date palm waste not only mitigates environmental pollution but also enhances cost efficiency and generates additional revenue by adding market value to these by-products. Reducing agricultural waste improves production efficiency without requiring additional farmland, alleviating environmental pressures, and reducing pollution. Lower waste levels lead to decreased production costs and improved product quality, which, in turn, increases the income of producers—particularly small-scale farmers.

Additionally, improved agricultural efficiency enhances food availability and nutrition, benefiting public health (Taheri et al., 2018). In many developing countries, high levels of agricultural waste result in financial losses and lower productivity in the agricultural sector. Thus, implementing effective waste reduction strategies is crucial to boosting food production and overall agricultural efficiency (Albozahr & Ahmadizadeh, 2005). Utilizing date palm waste presents a significant opportunity to promote sustainability across environmental, economic, and social dimensions. Environmentally, recycling and repurposing date palm waste can reduce pollution, enhance soil fertility, and increase water retention and nutrient availability—particularly through its conversion into biochar (Giwa et al.,

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2019; Karbout et al., 2019; Tahir et al., 2020; Khoshnodifar et al., 2023; Kavvadias et al., 2024). Additionally, composting date palm residues aids in the biocontrol of soil-borne phytopathogens (Ou-Zine et al., 2020), while palm peat serves as a viable growth substrate (Heidari et al., 2021; Ghehsareh et al., 2011). From an industrial perspective, date palm waste can be repurposed into biofuels to reduce dependence on fossil fuels or used as raw material for biodegradable composites, including chipboards, paper, and plastic wood in the wood and paper industries (Mohebbi Gargari et al., 2015; Belgacem et al., 2021). The food industry also benefits from utilizing date losses to produce fermented products such as palm alcohol, vinegar, and citric acid, as well as non-fermented products like date syrup (Majzoobi, 2015). Economically, repurposing date palm waste can stimulate job creation and economic growth (Khoshnodifar et al., 2023), ultimately improving the livelihoods of agricultural communities (Faiad et al., 2022). By aligning with global sustainability goals, the efficient utilization of date palm waste not only minimizes environmental impact but also enhances economic resilience and social well-being in regions where agriculture is a primary source of income.

According to the 2024 agricultural statistics, Khuzestan Province, located in southwest Iran, ranked second in annual date production after Fars Province. The total fertile area under date palm cultivation in Khuzestan spans 35,307 hectares, with 12,686 fertile date palm trees contributing to a total production of 316,838 tons. The yield per hectare is 8,954 kg for irrigated and 5,920 kg for rainfed date cultivation (Iran's Agricultural Statistics for 2023, 2024b). However, significant amounts of agricultural waste are lost annually due to the poor management practices and lack of mechanization in the agricultural industry (Badamchizadeh et al., 2021). By early 2024, among the 462 date grading and packaging industrial units across Iran, Khuzestan Province accounted for only 42, representing 9.1% of the total. Additionally, out of 126 date processing units in the country, Khuzestan had just 2, making up a mere 1.6% of the total (Iran's Agricultural Statistics for 2023, 2024a). Due to inadequate processing facilities and improper storage conditions, a substantial quantity of dates is wasted annually. It is estimated that 40% of total date production is lost, with 21% occurring between harvest and consumption due to the inefficiencies in post-harvest handling (Ahmadi & Barzegar, 2016). These statistics highlight the urgency of addressing the issue of date palm waste in Khuzestan and implementing effective strategies to mitigate these losses. To gain deeper insights into this issue, a review of relevant research on waste management, particularly in the context of agricultural products and date palm waste, was conducted. Several studies, including those by Sharifi et al. (2024), Sobati Gavgani (2014), and Pal et al. (2009) have identified various factors contributing to agricultural waste. These include outdated agricultural production methods, inadequate storage and transportation infrastructure, inefficient handling of agricultural goods, non-compliance with production standards, insufficient processing facilities for optimal raw material utilization, inappropriate consumption patterns, and lack of emphasis on food preparation. The research emphasizes that the establishment of processing and packaging industries can serve as an economically effective approach to reducing waste, thereby increasing efficiency and profitability for farmers. Similarly, studies conducted in Uganda indicate that 22% of fruit wastage is caused by delayed access to markets, limited farmer knowledge regarding market demands, and insufficient agricultural infrastructure (Kasozi & Mwegombi, 2007).

Managerial shortcomings, inefficient harvesting techniques, improper packaging methods, and inadequate information management further contribute to agricultural waste. Savari (2021) suggests that developing processing and supplementary industries can stabilize farmers' incomes, enhance profitability, and significantly reduce waste by mitigating price fluctuations during periods of high production. Further supporting this argument, Davarpanah et al. (2015), Azizi (2004), Bayat (2004), Sukhtanlu (2010), and Savari & Sharifi (2020) emphasize that expanding processing industries leads to a notable reduction in waste, particularly during transportation and distribution stages in agricultural supply chains. Irvan (2018) explored the potential of zero-waste technology in palm oil factories, highlighting how wastewater can be repurposed to produce biogas for electricity generation or boiler fuel. Additionally, the production of compost and charcoal from palm residues can contribute to reducing greenhouse gas emissions and minimizing environmental pollution. Similarly, Hambali & Rivai (2017) argue that there is significant potential in converting palm oil industry waste into valuable resources, such as using wastewater to generate electricity or transform solid waste into marketable by-products. In the case of date palm waste, Ou-Zine et al. (2020) highlight the benefits of composting date palm by-products using a forced aeration system, which enhances soil fertility and acts as a biocontrol agent against soil-borne phytopathogens. Despite these technological advancements, waste management strategies in many regions tend to focus primarily on economic and environmental aspects, often overlooking social considerations. Sustainable waste management requires a holistic approach that integrates environmental, economic, and social dimensions to ensure both effectiveness and community acceptance (Naqavi & Moradikia, 2019).

The literature underscores the critical role of agricultural waste, particularly from date palm trees, as a resource with significant potential to support sustainable practices and economic development. In Khuzestan Province, where date production is a major agricultural activity, the underutilization of date palm waste results in substantial losses each year. This issue stems from insufficient attention from both local authorities and growers, as well as a lack of investment in innovative waste management solutions. Consequently, there is an urgent need to implement targeted strategies that optimize the utilization of date palm waste while considering environmental, social, and economic factors. Therefore, this study aims to identify a range of strategies for utilizing date palm waste by taking into account the specific environmental, economic, and social conditions of Khuzestan Province. To achieve this goal, a SWOT analysis has been employed to assess the strengths, weaknesses, opportunities, and threats related to palm waste utilization for various purposes in the region. The research framework is provided in Fig. 1.

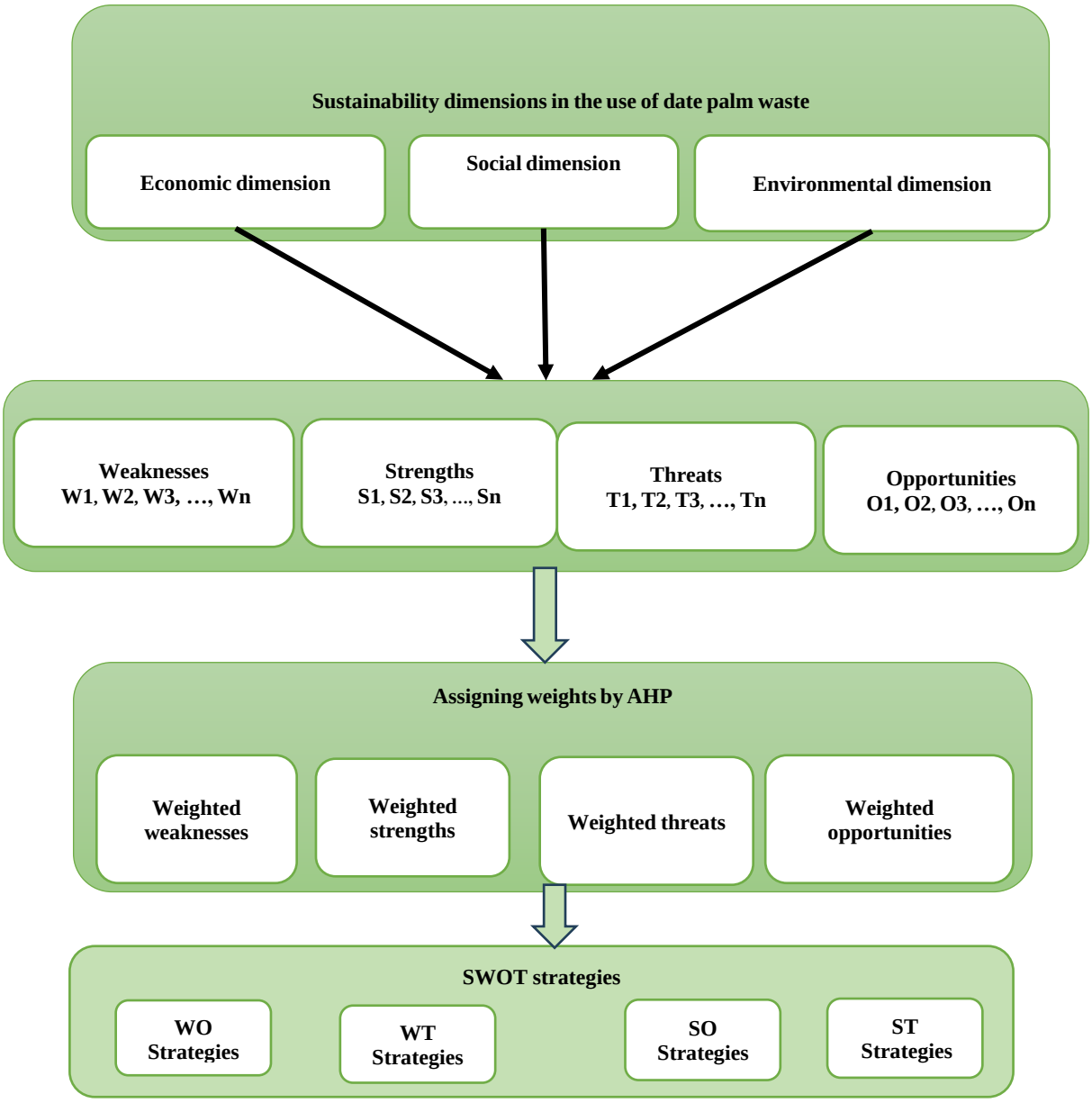

Fig. 1. Research framework.

MATERIALS AND METHODS

The study employed a survey methodology by integrating SWOT and AHP analyses to examine strategies for utilizing date palm waste in Khuzestan Province, southwest Iran. The research participants included 110 agricultural administrative experts from five leading date-producing regions. From this population, a sample of 79 experts was selected using the Krejcie and Morgan table and a simple random sampling method. Additionally, 12 experts specializing in palm cooperatives from the General Directorate of Cooperatives, Labor, and Social Welfare were included, along with 30 key informants from the members of palm growers' cooperatives in Khuzestan Province, which has a total membership of 500. These key informants were purposefully incorporated due to their direct involvement in palm waste management. Moreover, to conduct the AHP analysis, a purposeful sampling approach was adopted in collaboration with 9 faculty members and research experts from the Date and Tropical Fruits Research Institute, whose expertise contributed to a more in-depth understanding of the issue. The data collection process involved a combination of library research and fieldwork. In order to enrich the survey and enhance comprehension of the research topic, a literature review was conducted, along with preliminary interviews with an entrepreneur and two agricultural experts from Agricultural Jihad Administration in Bavi City. These individuals had previously collaborated with the palm growers' cooperative, and their insights helped in identifying the key strengths, weaknesses, threats, and opportunities associated with the use of date palm waste at the provincial level. The primary data collection instrument was a structured questionnaire designed to capture both the personal and professional characteristics of the participants, while also addressing the crucial elements of the SWOT model. The questionnaire was specifically developed for Khuzestan Province and covered a comprehensive range of aspects related to date palm waste management. It included 15 items for strengths, 14 for opportunities, 18 for weaknesses, and 13

for threats, with all aspects categorized into three dimensions: environmental, economic, and social. These dimensions were selected to ensure a holistic analysis of the various factors influencing the utilization of date palm waste. To ensure the validity of the questionnaire, it was reviewed and modified based on feedback from academics and experienced professionals in the fields of horticulture, agronomy, agricultural extension, and education. Their input helped refine the content, ensuring that it accurately addressed the research objectives. The questionnaire was then pilot-tested among 32 agricultural experts in Dezful and Bavi to assess its reliability. The Cronbach's alpha coefficients for each section of the questionnaire were calculated, as presented in Table 1, confirming that the research components, i.e., strengths, weaknesses, opportunities, and threats, were sufficiently reliable to proceed with the main study.

Table 1. Cronbach's alpha coefficient of the SWOT components

Component	No. of statements	Cronbach's Alpha coefficient
Strengths	15	0.87
Opportunities	14	0.86
Weaknesses	18	0.87
Threats	13	0.9

To analyze the data, the study employed SWOT (Strengths, Weaknesses, Opportunities, and Threats) and AHP (Analytical Hierarchy Process) methods, utilizing software such as SPSS, Excel, and Expert Choice for data processing. In the SWOT model, an effective strategy leverages strengths and opportunities while minimizing weaknesses and threats. This approach involves structuring the analysis into four key strategic categories: WT (Weakness-Threat), ST (Strength-Threat), WO (Weakness-Opportunity), and SO (Strength-Opportunity), each designed to guide informed decision-making. The analytical SWOT framework summarizing these categories is presented in Table 2.

Table 2. Analytical matrix framework for SWOT analysis

SWOT matrix	***Strengths (S)***	***Weaknesses (W)***
Opportunities (O)	*SO strategies*	*WO strategies*
Threats (T)	*ST strategies*	*WT strategies*

The analysis process using the SWOT model involved several key steps to systematically evaluate internal factors (strengths and weaknesses) and external factors (opportunities and threats). This included constructing matrices to assess these factors, prioritizing them based on their significance, developing the SWOT matrix, defining appropriate strategies, and formulating the Internal and External Matrix (IEM) to guide strategic planning. To ensure the validity and reliability of the questionnaire, the following steps were undertaken:

2.1. Creating the matrix to evaluate internal and external factors

This matrix consists of five components. Their method of measurement and calculation was as follows:

2.1.1. Internal and external factors

While the former cover strengths and weaknesses, the latter encompass opportunities and threats. By employing the research questionnaire, the current status of statements related to these factors, among the sample group, was assessed using a ranking system. This involved assigning a rating of 4 (very strong) or 3 (strong) for strengths, 2 (weak) or 1 (very weak) for weaknesses, also 4 (excellent opportunity) or 3 (normal opportunity) for opportunities, and 2 (minor threat) or 1 (serious threat) for threats (Mohammadinia *et al*., 2017).

2.1.2. Weight

The weight and significance of SWOT factors and their associated statements were determined using the AHP method.

2.1.3. Relative weight

To determine the relative weight of each statement related to internal factors, the total weight of the corresponding statements was first calculated separately. Each statement's weight was then divided by the total weight of all statements associated with the respective factor. A similar approach was applied to the evaluation matrix for external factors. The total weight for external factor statements was calculated separately, after which the weight of each statement was divided by the total weight of all statements linked to those factors. As a result, the relative weight of each statement was assigned a numerical value ranging between 0 and 1.

2.1.4. Ranking mean

At this stage, based on the data collected from the questionnaire, an average ranking value was calculated for each statement related to strengths, weaknesses, opportunities, and threats. The results showed that the statements associated with strengths and opportunities received average ranking values between 3 and 4, while the statements related to weaknesses and threats received values between 1 and 2.

2.1.5. Total score

The score for each statement was calculated by multiplying its relative weight by the mean ranking. Then, the total final scores—i.e., the sum of all individual scores—were determined for strengths, weaknesses, opportunities, and threats. If the total final score exceeded 2.5, it indicated that strengths are expected to outweigh weaknesses or that opportunities are likely to surpass threats, according to the predictions. On the other hand, a score below 2.5 suggests that weaknesses may prevail over strengths or that threats could overshadow opportunities (Saraei and Shamshiri, 2013; Mohammadinia et al., 2017).

2.2. Prioritizing internal and external factors

During this phase, the strengths, weaknesses, opportunities, and threats were ranked based on the final

scores resulting from the assessment of internal and external factors.

2.3. Developing of SWOT matrix and strategy determination

In this process, the factors prioritized by their final scores were first inserted into the SWOT matrix. Internal strengths were then aligned with external opportunities and threats, while internal weaknesses were similarly matched with the relevant external factors. Following this alignment, appropriate strategies were proposed to utilize date palm waste, categorized into four strategic types: Invasive Strategies (SO), Diversifying Strategies (ST), Conservative Strategies (WO), and Defensive Strategies (WT). These categories guided the development of targeted strategies for maximizing the use of date palm waste.

2.4. Formation of internal and external matrix

Establishing this matrix entailed inputting the scores from evaluating internal and external factors into a matrix with horizontal and vertical dimensions. The objective was to clarify the strategies' positions concerning each other and select the appropriate ones.

RESULTS AND DISCUSSION

According to the research findings, the total sample of experts and date palm growers surveyed exhibited an almost equal gender distribution. Most of the experts had a bachelor's degree (37.2%), while the majority of the date palm growers lacked academic education. In terms of field of study, the largest group of experts had backgrounds in agronomy, with 33 individuals (29.7%) in this category.

3.1. Recognizing internal and external elements

The results of the internal factors evaluation are outlined in Table 3. As shown in Table 3, the strengths with the highest scores include statements such as "There is a demand for by-products derived from date production waste (date syrup, basket, straw hat, etc.)" with a score of 0.274, "Using palm waste boosts activities and mobility among palm tree growers by offering employment opportunities and additional income" with a score of 0.26, and "The region has abundant date palm plantations" with a score of 0.245. Similarly, the weaknesses with the highest scores include statements like "Some date palm growers burn date waste" with a score of 0.148, "Some date palm growers leave date waste in the environment" with a score of 0.088, and "Date palm growers are not financially supported" with a score of 0.086. The total final score for strengths is 1.8521483, while for weaknesses, it is 0.8325315. Consequently, with the combined total score for strengths and weaknesses amounting to 2.6846798, which exceeds 2.5, it is concluded that strengths prevail over weaknesses. The assessment of external factors followed a similar process to the evaluation of internal factors, with the results presented in Table 4. In Table 4, statements related to opportunities, such as "Some palm growers do not dispose of or burn waste," which received a score of 0.527, and "Efficient utilization of waste in wood industries (particle board and MDF) is practiced in the region," which scored 0.299, received the highest ratings. Regarding threats, statements such as "The active workforce lacks interest in working in this sector" scored 0.194, and "Market constraints and currency fluctuations pose challenges for palm growers" scored 0.145, received the highest ratings. The total final score for opportunities in Table 4 is 1.5529988, while for threats, it is 0.963425. The combined final score for opportunities and threats is 2.5164238, illustrating that external opportunities outweigh external threats, though the difference is not significant when compared to the dominance index of 2.5. The results from Table 3 and Table 4 suggest that, due to the dominance of strengths over weaknesses and the greater value of opportunities compared to threats, utilizing date palm waste is not only feasible but also economically beneficial.

3.2. Creating the SWOT matrix and determining the strategies

In Table 5, internal strengths and weaknesses were compared with external opportunities and threats. Following this, suitable strategies for maximizing the utilization of date palm waste were categorized into four strategic groups: SO, ST, WO, and WT Strategies. These strategies were developed with consideration of environmental, social, and economic factors, as provided in Table 5, Table 6, and Table 7.

3.2.1. Environmental strategies

As shown schematically in Table 5, environmental strategies for maximizing the use of date palm waste are proposed as:

SO1en: Setting up agricultural cooperative firms for buying palm waste and emphasizing on the efficient use of such waste for value-added production;

SO2en: Replacing inappropriate varieties with the cultivation of superior date palm varieties suitable for the climatic conditions of each region;

WO1en: Enhancing intermediary services in collecting remnants and transporting them to processing centers;

WO2en: Forcing palm growers to gather palm waste from the surrounding environment;

WO3en: Introducing and highlighting the value of lignocellulosic resources for replacing tree wood in wood industries;

ST1en: Promoting high-quality and resilient varieties that are resistant to dust and soil salinity;

ST2en: Establishing penalty plans for burning palm waste and encouragement programs for converting waste into usable materials;

WT1en: Holding educational workshops to educate palm growers on identifying products made from palm and date waste.

Table 3. Internal factors evaluation (IFE) matrix

	Internal factors (strengths and weaknesses)	Weight score	Relative weight	Mean rank of 4	Final score
Strengths	S_1: The region has abundant date palm plantations	0.383	0.064	3.84	0.24576
	S_2: After pruning palm trees, the remaining materials are available to palm tree farmers	0.276	0.046	3.724	0.171304
	S_3: The climate of the region is perfect for cultivating palm trees	0.220	0.037	3.918	0.144966
	S_4: The region is home to a variety of date palm species (genetic bank)	0.120	0.02	3.706	0.07412
	S_5: There exists a cooperative of palm tree growers in the region	0.223	0.037	3.546	0.131202
	S_6: Using palm waste boosts activities and mobility among palm tree growers by offering employment opportunities and additional income	0.427	0.071	3.666	0.260286
	S_7: There is an agricultural sciences university and also related research institution in the region	0.129	0.022	3.724	0.081928
	S_8: Handicrafts related to palm trees are widespread in the region	0.161	0.027	3.5629	0.0961983
	S_9: Training courses and workshops are conducted for palm tree farmers	0.060	0.01	3.447	0.03447
	S_{10}: Date palm by-products are used as animal feed	0.268	0.045	3.4796	0.156582
	S_{11}: Palm waste is used in handicraft industries	0.110	0.018	3.594	0.064692
	S_{12}: There is a significant workforce in rural areas	0.043	0.007	3.837	0.026859
	S_{13}: Reducing date palm waste and optimizing its use enhances the economic power of the region	0.088	0.015	3.758	0.05637
	S_{14}: Handicrafts created from date palm leftovers are well-received in both local and international markets	0.053	0.009	3.659	0.032931
	S_{15}: There is a demand for by-products derived from date production waste (date syrup, basket, straw hat, etc.)	0.438	0.073	3.76	0.27448
Total score of strengths		3.089	0.501	55.2215	1.8521483
Weaknesses	W_1: Some date palm growers burn date waste	0.527	0.088	1.6825	0.14806
	W_2: Some date palm growers leave date waste in the environment	0.335	0.056	1.578	0.088368
	W_3: Burning of the natural and lignocellulosic resources results in their depletion	0.138	0.023	1.704	0.039192
	W_4: Government and official institutions have not supported the cooperatives of palm tree growers	0.066	0.011	1.619	0.017809
	W_5: The deficiency of essential infrastructure (including sanitary cold storage, suitable transportation means, MDF and chipboard factories, and processing industries for date palm waste) is clearly evident	0.048	0.008	1.751	0.014008
	W_6: The organizations overseeing agricultural industries lack coordination among themselves	0.277	0.046	1.621	0.07566
	W_7: Dates are harvested in a traditional, non-mechanized way	0.163	0.027	1.774	0.047898
	W_8: There is unethical competition among date exporters	0.082	0.014	1.622	0.022708
	W_9: There are no regulatory and supportive organizations for marketing and export operations	0.133	0.022	1.631	0.035882
	W_{10}: Weakness in agricultural extension programs	0.195	0.033	1.529	0.050457
	W_{11}: The educational programs of the provincial broadcasting network demonstrate a lack of strength	0.036	0.006	1.554	0.009324
	W_{12}: Resources with the potential to create added value are being wasted	0.049	0.008	1.64	0.01312
	W_{13}: Proper packaging of goods is absent in the region	0.040	0.007	1.646	0.011522
	W_{14}: There are no affordable and convenient facilities for the development of processing industries	0.075	0.013	1.681	0.021853
	W_{15}: The robust marketing and distribution system for manufactured products and production support services are absent	0.122	0.02	1.653	0.03306
	W_{16}: There are no pilot projects for utilizing waste materials	0.147	0.025	1.6767	0.0419175
	W_{17}: The transportation expenses for exports are excessively costly	0.263	0.044	1.742	0.076648
	W_{18}: Date palm growers are not financially supported	0.304	0.051	1.689	0.086139
Total score of weaknesses		2.98	0.502	29.7932	0.8325315
Total Score		5.999	1	85.0147	2.6846798

Table 4. External factors evaluation (EFE) matrix

	Internal factors (opportunities and threats)	Weight score	Relative weight	Mean rank of 4	Final score
Opportunities	O_1: There is a plentiful supply of date palm waste in the region	0.180	0.033	3.739	0.123387
	O_2: Some palm tree growers do not dispose of or burn the waste	0.820	0.151	3.491	0.527141
	O_3: Transforming palm waste into marketable products leads to the generation of employment, additional income, and sustainability	0.326	0.006	3.647	0.021882
	O_4: Effective utilization of palm waste reduces seasonal and periodic unemployment	0.202	0.004	3.586	0.014344
	O_5: There are social and information networks available for learning about various applications	0.116	0.002	3.369	0.006738
	O_6: A research center for date palms and tropical fruits has established to conduct advantageous and impactful applied research in the region	0.055	0.01	3.532	0.03532
	O_7: There is the opportunity to organize and take part in international and regional exhibitions	0.038	0.007	0.123387	0.02457
	O_8: There are skilled and specialized persons in the date processing industries at the provincial level	0.169	0.031	0.527141	0.108655
	O_9: The practice of palm cultivation and its indigenous knowledge is present among the local people	0.094	0.017	0.021882	0.061999
	O_{10}: Efficient utilization of waste in wood industries (particle board and MDF) is practiced in the region	0.484	0.089	0.014344	0.2992358
	O_{11}: The transformation of waste has resulted in generating foreign currency	0.246	0.045	0.006738	0.154395
	O_{12}: Date palm waste is conventionally utilized in processing and supplementary industries	0.093	0.017	0.3532	0.058684
	O_{13}: It is easier to sell processed products of processing and supplementary industries	0.076	0.014	0.02457	0.05201
	O_{14}: Palm waste is utilized for making compost and palm peat	0.101	0.019	0.108655	0.064638
Total score of opportunities		2.4204	0.446	49.3882	1.5529988
Threats	T_1: The incineration of palm waste causes environmental pollution	0.373	0.069	1.745	0.120405
	T_2: Environmental pollution is caused by discarding palm waste in the environment	0.391	0.072	1.685	0.12132
	T_3: Climate change such as dust storms causes the decrease in product yield	0.159	0.029	1.72	0.04988
	T_4: The saltiness of water and soil, prevalent in the region, adversely affects the palm cultivation industry	0.080	0.015	1.848	0.02772
	T_5: The active workforce lacks interest in working in this sector	0.631	0.116	1.678	0.194648
	T_6: The significant volume of waste and its material value do not receive enough attention	0.096	0.018	1.716	0.030888
	T_7: The lack of effectiveness in the management system has resulted in the unprofitability of palm cultivation	0.273	0.05	1.756	0.0878
	T_8: Market constraints and currency fluctuations pose challenges for palm growers	0.443	0.082	1.779	0.145878
	T_9: Sufficient investment and appropriate policy-making have not been implemented in the processing and supplementary industries	0.210	0.039	1.78	0.06942
	T_{10}: Palm growers lack access to facilities and equipment	0.040	0.007	1.795	0.012565
	T_{11}: There are no specialized and supportive funds available, and the conditions for accessing facilities are challenging	0.085	0.016	1.89	0.03024
	T_{12}: There are more lucrative sectors than palm cultivation	0.166	0.031	1.761	0.054591
	T_{13}: Manufacturer in pertinent industries do not receive subsidies	0.055	0.01	1.807	0.01807
Total score of threats		3.002	0.554	22.96	0.963425
Total Score		5.4224	1	72.3482	2.5164238

3.2.2. Social strategies

As shown in Table 6, a number of strategies can be proposed that take social aspects into account:

$SO1_S$: Utilizing the expertise potential of universities and research institutions, along with employing specialized professionals in processing industries;

$SO2_S$: Steering objectives of palm growers' cooperative towards further reducing palm and date waste, and utilizing the waste in associated processing and supplementary industries;

$SO3_S$: Hosting diverse festivals to showcase date and palm by-products and establishing local markets for direct consumer sales;

SO4s: Incorporating genetic engineering and biotechnology in producing suitable varieties aimed to reduce waste;

So5s: Motivating agricultural students to establish startups to turn waste reduction concepts into economic ideas of product development and commercialization;
SO6s: Fostering rural entrepreneurship to produce various goods from date palm waste;
SO7s: Establishing women's cooperatives in regions specializing in date palm cultivation to produce handicrafts, supported by entities like the Agricultural Jihad Organization and the Provincial Cooperation Department for both domestic and international marketing;
WO1s: Organizing classes and training sessions to enhance the knowledge and skills of date palm growers and their families about the various products made from palm waste, unconventional date harvesting methods and taking advantageous of provincial broadcasting to showcase successful projects and the value of palm waste;
WO2s: Initiating a local factory for converting waste into particleboard and MDF with the backing of the governorate;
WO3s: Conducting training workshops by the Agricultural Jihad Organization on utilizing waste and strategies for waste reduction;
ST1s: To introduce employment opportunities in palm waste-related industries to the members of date palm growers' cooperative;
ST2s: Extending insurance services and offering targeted supportive measures for processing and complementary industries to enhance job security and promote investment, aiming to incentivize active workforces to engage in this sector;
ST3s: Directing the research strategies of the provincial University of Agricultural Sciences and Natural Resources towards planning and implementing practical and educational initiatives focused on reducing date palm waste in the region within a defined timeframe;
WT1s: Placing strong emphasis on setting up date processing industries as a key objective in the region's development plan by involving all relevant bodies, such as the governorate, Agricultural Jihad Organization, and Cooperative and Social Welfare General Administrative;
WT2s: Organizing training programs to educate and enhance palm growers' interest in reusing and converting waste into organic fertilizer.

3.2.3. Economic strategies

Table 7 shows schematically the strategies considering the economic aspects. In detail, these strategies are as follows:
SO1ec: Producing livestock feed from palm leaves using a shredder machine and adding supplementary materials;
SO2ec: Establishing a particleboard manufacturing factory for waste utilization and job creation;
SO3ec: Hosting exhibitions of products and handicrafts made from waste in tourist-attracting areas in the province;
SO4ec: Educating, extension, and enhancing palm-related handicraft industries with support for domestic and international marketing;
SO5ec: Initiating small rural workshops for producing compost and palm peat;
SO6ec: Expanding the industrial sector, especially processing and supplementary industries, in the region;
WO1ec: Establishing coherence among different organizations to enhance coordination in the field;
WO2ec: Encouraging private investors to develop processing and supplementary industries in date-growing regions;
WO3ec: Establishing MDF and particleboard factories to utilize wood waste;
WO4ec: Providing low-interest loans to potential entrepreneurs for starting processing industries or wood-related ventures;
WO5ec: Supporting and monitoring the marketing and distribution system of date palm products;
WO6ec: Improving infrastructure such as sanitary cold storage and suitable transportation means, etc.
ST1ec: Establishing credit funds and offer low-interest financial assistance to industries related to date palm;
ST2ec: Addressing and resolving marketing issues through the efforts of relevant officials;
ST3ec: Encouraging and motivating young job seekers in rural areas to engage in date palm cultivation by providing subsidies;
WT1ec: Setting up dedicated rural cooperatives to efficiently deliver date palm products to markets or processing industries in a timely manner;
WT2ec: Offering low-interest loans and facilities to rural residents involving in date palm production;
WT3ec: Providing agricultural mechanization to palm growers to decrease harvest losses.

Formation of IEM

To select appropriate strategies, the combined scores from the final assessments of the IFE matrix (2.68) and EFE matrix (2.51) were plotted on specific coordinate axes to determine the strategic positions considering all factors. Depicted in Fig. 2, it was evident that to enhance the utilization of date palm wastes, applying Invasive Strategies (Cell 1) is advisable. This cell indicates that considering the current internal and external conditions of date palm plantations, employing Invasive Strategies (utilizing strengths, maximizing opportunities) is recommended to improve the situation.

Table 5. Matrix of the developed strategies for environmental dimension

Internal factors / **External factors**	**S**		**W**
	S1, S2, S3, and S4		W1, W2, and W3
O	O1 and O2	Invasive strategies (SO)	Conservative strategies (WO)
		SO1 and SO2	WO1, WO2, and WO3
T	T1, T2, T3, and T4	Diversifying strategies (ST)	Defensive strategies (WT)
		ST1 and ST2	WT1

Table 6. Matrix of the developed strategies for social dimension

Internal factors / External factors	S		W
	S5, S6, S7, S8, and S9		W4, W5, W6, W7, W8, W9, W10, and W11
O	O3, O4, O5, O6, O7, O8, and O9	Invasive strategies (SO)	Conservative strategies (WO)
		SO1, SO2 SO3, SO4, SO5, SO6, and SO7	WO1, WO2, and WO3
T	T5, T6, and T7	Diversifying strategies (ST)	Defensive strategies (WT)
		ST1, ST2, and ST3	WT1 and WT2

Table 7. Matrix of the developed strategies for economic dimension

Internal factors / External factors	S		W
	S10, S11, S12, S13, S14, and S15		W12, W13, W14, W15, W16, W17, and W18
O	O10, O11, O12, O13, and O14	Invasive strategies (SO)	Conservative strategies (WO)
		SO1, SO2 SO3, SO4, SO5, and SO6	WO1, WO2, WO3 WO4, WO5, and WO6
T	T8, T9, T10, T11, T12, and T13	Diversifying strategies (ST)	Defensive strategies (WT)
		ST1, ST2, and ST3	WT1, WT2, and WT3

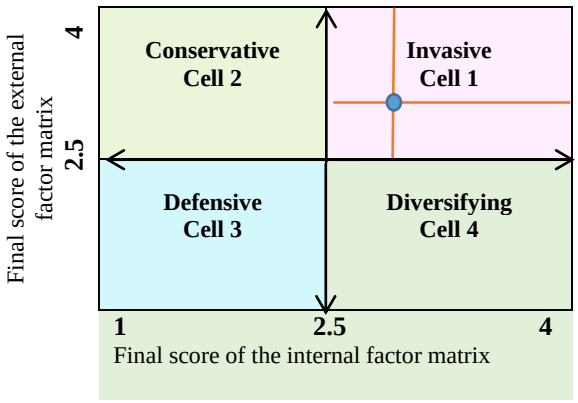

Fig. 2. Strategic position of different strategies for utilizing date palm waste.

The findings emphasize that with the use of SWOT analysis and strategic planning, the potential benefits of utilizing date palm waste can far surpass the challenges currently faced. By adopting innovative approaches and engaging stakeholders at all levels, date palm waste management in Khuzestan Province can be transformed into a model of sustainability that balances environmental health with economic prosperity. In this context, invasive strategies encourage the development of collaborations and the creation of new products from date palm waste, positioning them to capture emerging market trends and consumer preferences. The proposed environmental strategies for maximizing date palm waste utilization, as outlined in Table 5, focus on two main approaches: the establishment of agricultural cooperatives for efficient waste utilization (SO1en) and the breeding of superior date palm varieties (SO2en). These strategies aim to increase the sustainability and productivity of date palm cultivation while addressing the environmental concerns associated with waste management. The invasive social strategies for date palm waste utilization, as detailed in Table 6, stress the integration of social factors into waste management practices. These strategies seek to engage various stakeholders, such as academic institutions, palm grower cooperatives, allied industries, local markets, rural entrepreneurs, and knowledge-based start-ups to enhance the sustainability of date palm waste management. These social strategies are closely linked to the economic strategies for date palm waste utilization, including SO1ec to SO6ec. Through invasive strategies, innovative by-products such as organic fertilizers, biochar, natural fiber composites, syrups, and other date palm-based food materials can quickly enter new markets or expand existing ones, thus increasing demand for products derived from date palm waste. These findings align with those of Savari (2021), Savari and Sharifi (2020), Patel et al. (2023), Kavvadias et al. (2024), Khoshnodifar et al. (2023), Faiad et al. (2022), Giwa et al. (2019), Karbout et al. (2019), Tahir et al. (2020), Ou-Zine et al. (2020), Heidari et al. (2021), Ghehsareh et al. (2011), and Belgacem et al. (2021). Furthermore, these strategies aim to create employment opportunities and stimulate local economic growth, contributing to the sustainable development of regions with significant date palm cultivation.

CONCLUSION

Agricultural waste, particularly from date palms, represents a significant yet underutilized resource, especially in regions like Khuzestan Province, Iran. This province is renowned

for its large-scale date production, but a substantial portion of this resource goes to waste due to poor management and a lack of awareness among farmers and local authorities. This situation offers a unique opportunity to implement strategies aimed at improving the utilization of date palm waste, which includes not only the fruit but also the leaves, branches, and other by-products. The findings of this study emphasize that date palm waste is not merely a by-product, but a valuable resource that can contribute to sustainable practices. By effectively managing and utilizing this waste, growers can mitigate environmental impacts and generate significant economic benefits. The research indicates that the strengths associated with date palm waste utilization, such as its potential for bioenergy production, the creation of new markets, composting, and the production of biodegradable products, far outweigh the current weaknesses, including poor management practices. Additionally, the external opportunities for utilizing date palm waste also outweigh the associated threats. The emphasis on invasive strategies suggests a proactive approach to overcoming the challenges of date palm waste management. Implementing effective strategies involves several key areas:

1. Technological innovation: The adoption of advanced technologies to process date palm waste can open up avenues for producing biofuels, biodegradable products, and other valuable materials that benefit both the environment and local economies. Furthermore, replacing inferior date palm varieties with those better suited to the region's climate can improve both yield and quality while reducing waste. Collaborating with research institutions on genetic engineering could lead to the development of more efficient date palm varieties that generate less waste. Additionally, encouraging students to create knowledge-based businesses can foster innovative solutions for waste reduction and product commercialization.
2. Economic viability: There are substantial financial incentives for farmers to invest in waste management systems. By converting waste into marketable products, farmers can boost their income while also contributing to environmental sustainability. Forming cooperatives allows growers to pool resources, making it easier to purchase and process date palm waste for value-added products. Additionally, investing in processing industries can generate jobs and ensure that agricultural waste is efficiently utilized, promoting economic growth in the region.
3. Environmental benefits: Proper use of agricultural waste helps reduce pollution and improves soil health through organic amendments. This is in line with global efforts to reduce making wastes and improve resource efficiency.
4. Social impact: Engaging local communities in initiatives to utilize date palm waste can foster social cohesion and create employment opportunities in emerging industries. Empowering rural women to craft handicrafts from date palm waste not only generates income but also helps preserve and promote local culture and craftsmanship. Additionally, hosting festivals and establishing local markets can raise awareness and appreciation of date palm by-products, encouraging community participation in sustainable practices and further driving the adoption of waste utilization.

In summary, the conclusion highlights the importance of strategic action to optimize the utilization of date palm waste in Khuzestan Province. This approach aligns with broader sustainability objectives, viewing waste not merely as a by-product, but as a valuable resource that can fuel new products and processes. Through innovative practices and active community involvement, stakeholders can address environmental issues while fostering economic growth and social development. The proposed strategies offer a clear roadmap for achieving these goals, stressing the need for collaboration among producers, researchers, and local communities to create a sustainable and prosperous future.

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AUTHORSHIP CONTRIBUTION STATEMENT

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DECLARATION OF COMPETING INTEREST

The authors declare no conflicts of interest.

ETHICAL STATEMENT

Ethics approval was obtained from the Ethics Committee of the Agricultural Sciences and Natural Resources University of Khuzestan, Iran. In addition, the participants provided their informed consent to participate in this study.

DATA AVAILABILITY

All relevant data will be made available from the author on request.

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