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Understanding the perceived indicators of food sovereignty and food security for rice growers and rural organizations in Mazandaran Province, Iran

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Abstract

Background: Food sovereignty and food security are inseparable from agricultural development policies, particularly regarding how to increase food production and productivity to meet future demand. This study investigates the status and perceptions of food sovereignty and food security of small-scale rice growers' households in the Mazandaran Province of northern Iran. The study region is one of the most important places for domestic rice production, with nearly 230,000 hectares of rice lands in the country and 45% of total domestic rice production. The role of the Rice Research Institute of Iran (RRII) as an innovative rural institution was highlighted by the rice producers for contributing to food sovereignty and food security. A survey was distributed among 127 rice farmers' households to obtain indicators of food sovereignty (localization of food systems, values for food providers, concentration of local control of the food system, building knowledge and skills, right to food, working with nature) and food security (availability, accessibility, utility, quality). Principal Component Analysis and Partial Correlation tests were used for finding the relationship between variables and focused indicators.

Results: Results show that food sovereignty in Northern Iran focused on localizing the food system by gaining access to financial assets and local markets, investing in human capital and local training and improving access to the water resources; food security focused on environmental and climate extension, increasing household's revenues by improving food policies and food quality from rice farmers' perspectives. In addition, the results of this study demonstrate the desire in Northern Iran for the role of innovative rural organizations as vital linkages between rice farmers and the public sector (i.e., Ministry of Agriculture Jihad).

Conclusions: This research shows that from the perspective of the surveyed rice growers in northern Iran, four main indicators that relate to investment and resources were the most significant: capital, markets, credit, and knowledge. Further studies are required for remote sensing monitoring of rice crop condition and yields, condition of irrigation systems, and geographic relationship of the agricultural infrastructure to food sovereignty and food security in northern Iran.

Keywords: Food security, Food sovereignty, Rural organizations, Rice growers

Introduction

Food security and food sovereignty are considered inseparable from international development policies [1], as well as crucial to domestic food policies [2]. A variety of indicators have been proposed to establish which

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countries are in need of improved food security status [3]. The definition of household food security is the physical, social, and economic access of members of the family to healthy, complete, sufficient and consistent diets that satisfy dietary requirements, and their willingness to maintain a healthy lifestyle [4]. Access to adequate healthy and nutritious foods, including avoiding hunger, are essential for food security [5]. Food sovereignty refers to the right of communities, people, and states to independently determine their own food and agricultural policies and practices [6]. This can entail the production of food through access to land and natural resources for food production [7]. Food sovereignty also includes the people's right to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture system [8, 9]. A country that cannot feed itself is not food sovereign nor food secure. Food security is a significant challenge, compounded by global economic crises, climate change, and compromised food production leading to rising food prices and rising numbers of malnourished people in rural areas [10]. Combining different food security indicators is an important strategy to holistically assess the food security status of the local population [11]. In essence, food sovereignty is a precondition to genuine food security [9].

Iran is a country in Western Asia with 82 million inhabitants and is the world's 18th most populous country. In Iran, as in many developing countries, issues of food insecurity are devastating and oppressive [12]. Food insecurity in chronic, seasonal, and transitory forms exists at the household, regional, and national levels and includes quantitative, qualitative, sociocultural, and psychological dimensions [13]. Poverty and food insecurity are closely interrelated, insufficient food and poor nutrition have major effects on human health, reduce human development—and in the long-run—reduce labor productivity [14]. Behzadifar et al. [15] show that the prevalence of food insecurity is high in Iran, with 49% of households, 67% of children, 61% of mothers, 49% of adolescents, and 65% of the elderly experiencing food insecurity. In addition, The FAO reports that from 2018 to 2020 the prevalence of moderate or severe food insecurity in the total population of Iran (~ 84 million) was 42.5% and the prevalence of undernourishment was 5.5% [16]. Strategies to increase food security are being sought through agricultural and rural development [17]. Based on 2018 United Nations Food and Agriculture Organization (UN FAO) reports, the number of people undernourished in Iran was close to 4 million, or roughly 4.6% of the population. Rice is the staple food for nearly half of the global population (more than 3 billion people) [18]. About 90% of the global rice is produced and consumed

in Asia, including Western Asia. Hence, rice production in Asia is the key for global food security [19] as well as local food security. In many developing countries, rice is the primary source of nutrition [20]. Many studies show great potential for increasing rice production [21] including Iran, where rice is mainly produced in the northern region near the Caspian Sea [22]. Food security in West Asia has traditionally been defined as maintaining basic prices for rice in rural markets, which provide the main food supply to more than 50% of the population. Reaching self-sufficiency in terms of rice production is, therefore, an effective method to promote food security at the national level [23].

Government-funded rural institutions (e.g. Rice Research Institute of Iran as a part of Agricultural Research, Education and Extension Organization (AREEO) which was officially founded in 1993 by the Ministry of Agriculture Jihad), which have more flexibility and access than the Ministry of Agriculture, have a positive effect on creativity and innovation by creating a network between small producers, small producer organizations, market actors, and policy makers [17]. Rural institutions, which have provincial headquarters also enhance life in rural areas through distributing information and building local resources and capacity, increasing access to natural resources and local governance, and facilitating pathways to production assets and markets [10]. Innovation in agriculture is a combination of new knowledge and technologies related to producing, processing, and commercializing agricultural commodities, thus improving productivity and competitiveness among diverse sectors of the rural population [24]. Organizational innovation is a broad concept that encompasses strategies, structural, and behavioral components [25]. One of the main functions of innovative rural organizations is to improve food security by creating a link between the public and private sectors that strengthens the governance of natural resources, such as water and land [26]. The Rice Research Institute of Iran (RRII, <http://rriiran.ir/index.php/mission/>) is an innovative rural institution and leader in rice research with a focus on climate change and irrigation water scarcity across the country's paddy fields to fulfill the current needs of farmers. RRII's mission and purpose is to improve the quality of life for those who depend on the rice sector, through augmenting rice-based agri-food systems and the environmental sustainability of rice production systems [27].

Considering population growth rates (1.3% for Iran) and limited water resources, it is anticipated that food security will be a serious challenge in the near future for Iran [28]. The agricultural sector in Iran is one of the country's most important economic sectors, with water being the most constraining factor for production,

despite the fact that agriculture uses more than 90 percent of the country's renewable water [29]. Because of low irrigation efficiency, about 50 to 60 percent of renewable water is lost in agriculture, and this has caused agricultural water productivity to be very low [21]. Improving access as well as promoting optimal management of water resources is crucial to sustainable and sufficient rice production.

The main goal of this research is to examine factors of rural food security and food sovereignty of rice producers in Northern Iran, with consideration of the role of rice organizations, such as the RRII. We used statistical approaches to analyze surveys and interviews conducted with 127 local rice producers in the region. In developing the surveys and interviews, we considered the major issues of food security and food sovereignty to be:

- Availability, accessibility, utility, and quality of food
- Local control and local governance issues
- Lack of small-scale farmers' access to financial assistance, knowledge, and information, as well as human capital and natural resources (e.g., water)
- In appropriate management patterns in rural areas that should be amended by innovative rural institutions

Materials and methods

Study area description

The study was conducted in the Mazandaran province of Iran (Fig. 1), which is one of the most important places for domestic rice production with nearly 230,000 hectares of rice lands in the country and 45% of total domestic rice production [30]. In Mazandaran, rice is planted mostly under irrigated conditions (i.e., paddy) and is grown and harvested once a year, from early April to early August, but sometimes is double-cropped with a shorter season between late August to early November [31]. Local media reports 214,326 hectares of total fields in Mazandaran under rice cultivation, with 204,127 hectares, or approximately 95%, via mechanized agriculture and the remaining 10,673 hectares grown using traditional methods [31]. Farmers have adopted a number of high yielding varieties, such as highly sought after *Tarom*, *Hasehmi*, *Binam*, *Fajr*, and *Shiroodi* [27]. They have used hybrid technologies to produce hybrid rice with consistently high-yield heterosis (hybrid vigor), good grain quality, tolerance to key environmental stresses, multiple resistances to insect pests and diseases, and high seed production yield [27]. Furthermore, more than half of the labor in rice fields, especially for paddy transplanting, is performed by women [23, 32].

Mazandaran Province, in northern Iran (Fig. 1), is one of the most important places for producing domestic rice within the country [31]. The intensive cultivation of rice in the region makes it susceptible to unsustainability [22]. Since no comprehensive study on the food security and food sovereignty of rice production in the region has been carried out, this study was an attempt to assess the indicators of food security and food sovereignty by posing questions and gathering the rice farmers' opinions. The resulting components highlight the importance of localizing the food system by increasing access to financial assets and local markets, investing in human capital and local training, accessing and managing water resources as well as environmental and climate extension offices, and increasing household revenues by improving food policies and food quality (QA/QC labs) from rice farmers' perspectives.

Research questions

This work seeks to answer the following question using the self-reported data from surveys:

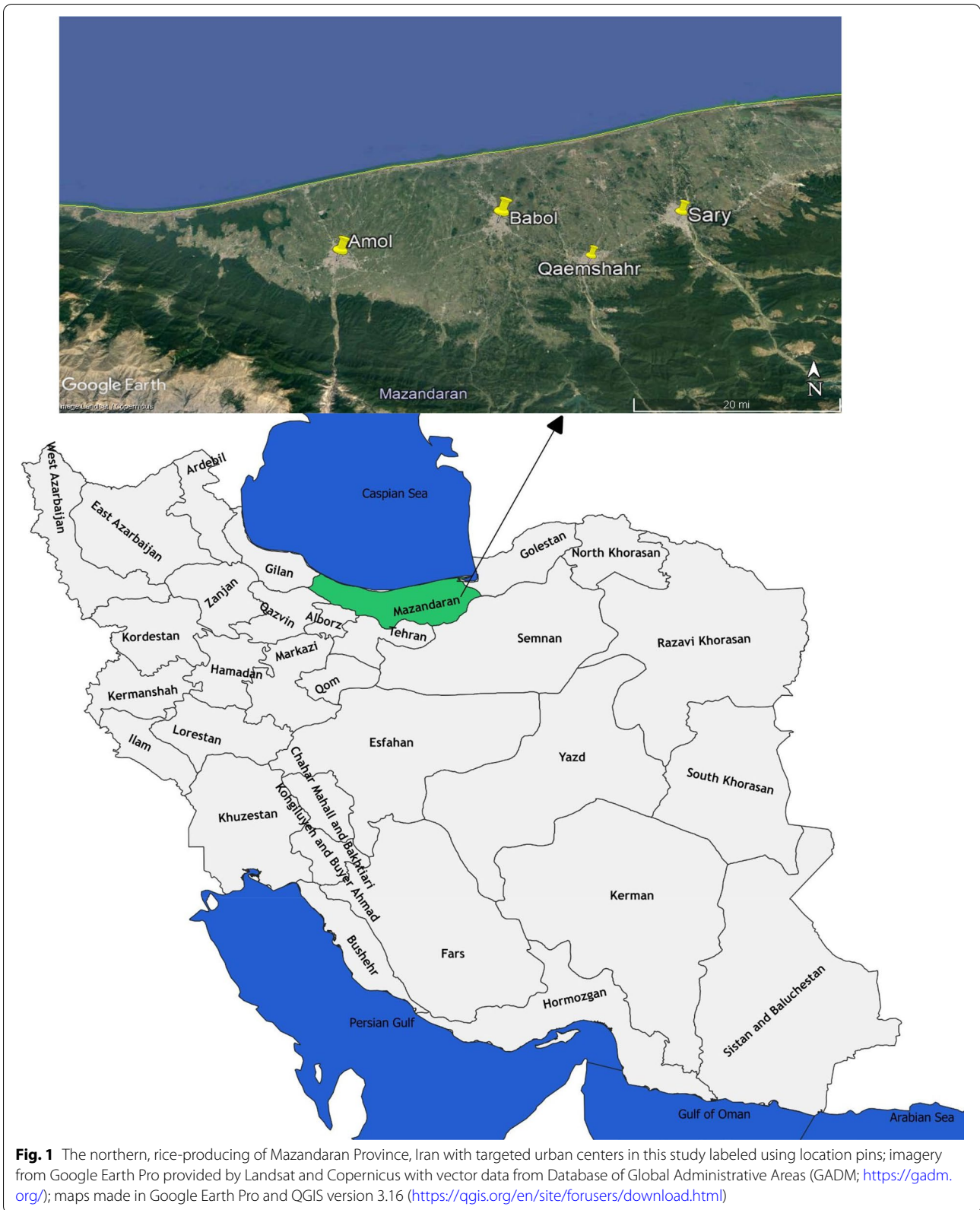
- What indicators explain food sovereignty and food security in rural rice growing communities of Northern Iran from the perspective of the farmers?

A series of sub-questions are answered in the analysis, including:

- What are the relationships between the six published indicators dimensions of food sovereignty as perceived by rice growers in northern Iran?
- How are the four published indicators of food security interrelated with each other and which ones contributed more?

Sampling and data collection

Data for scale development and validation were collected between June 2017 and March 2018 in Mazandaran Province, Iran. This stage of the analysis was prolonged due to the implementation of the Delphi method for survey creation, communication and outreach to farmers, and travel time to remote farms and fields for the interviews and surveys themselves. Scale development and validation are critical to much of the work in health, social, and behavioral sciences. There are three phases to creating a rigorous scale—item development, scale development, and scale evaluation. These can be further broken down into nine steps which include: (1) identification of the domain(s) and item generation; and (2) consideration of content validity. The second phase, scale development, i.e., turning individual items into a harmonious and



measurable construct, consists of (3) pre-testing questions; (4) sampling and survey administration; (5) item reduction; and (6) extraction of indicators (listed below). The last phase, scale evaluation of the accuracy of the survey mechanism, requires: (7) tests of dimensionality; (8) tests of reliability; and (9) tests of validity [33]. To test the validity of the questionnaire, a panel of rice experts at the RRII examined the questionnaire using the Delphi method and necessary modifications were made for the final version. For a more effective assessment of the quality and quantity of mediating factors, measures may include the Delphi method (quality) which is a technique “for structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem” [34]. The reliability of the questionnaire was tested using Cronbach’s alpha coefficient (Eq. 1; [35]) in the commercial statistical software SPSS. For the pre-test, 30 questionnaires were distributed among the rice growers to calculate Cronbach’s alpha, with answers entered into SPSS and after calculating the reliability for each indicator, results showed $0.94 < \alpha < 0.96$, indicating reliability had been confirmed:

$$\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N - 1) \cdot \bar{c}} \quad (1)$$

where N =the number of items, \bar{c} =average covariance between item-pairs, and \bar{v} =average variance.

Based on the stratified random sampling method with proportional allocation, 127 heads of smallholder farming households were selected as our targets, because they owned ≤ 1 hectare of fields actively cultivated in rice. Due to inheritance rules of land ownership and local customs, 93% of the heads of households were male and just 7% were female, but much of the self-reported data from the surveys and local media reports that half of the paddy rice labor are women [32]. Surveys comprised of 37 questions were distributed, with most farmers participating along with in-depth interviews. Table 1 shows the number of rice growers per selected city. Data collection was implemented through face-to-face survey and a questionnaire consisting of close- and open-ended questions was distributed among rice growers. Surveys and interviews were conducted in Farsi by lead author Zamanialaei. The close-ended questions section responses used the Likert scale from very high (1) to very low (5), a common summated rating format for surveys. The data collection targeted multiple households across the rural and urban gradient of the study area (Table 1).

Analytical framework

This study used published indicators of food security and food sovereignty but defined regionally specific variables

Table 1 Target cities and surrounding agricultural areas in Mazandaran Province, Iran to interview rice growing household

City	Number (percent) of sampled households
Babol	44 (35%)
Sary	26 (20%)
Amol	36 (28%)
Qaemshahr	21 (17%)
Total	127

to analyze food security and food sovereignty, building off of the peer-reviewed literature. Qualitative and quantitative methods have been used to estimate the importance of each indicator from the point of view of rice growers of Mazandaran Province, Iran (Table 2).

In this real-world agricultural community, the definitions for food security and food sovereignty have an applied focus on the livelihoods of the rice growers and their households as well as the associated rural organization of RRII. For our study region, food security is defined as a sufficient quantity of rice produced locally that is available for household consumption at all times. For the Mazandaran Province, food sovereignty is defined as total production under control of the rice growers’ households as well as sufficient access to natural resources, specifically water and land (i.e., soil treatments, fertilizer, pesticides, and herbicides), to manage their lands. A flowchart is shown in Fig. 2.

The surveys included 20 questions from six indicators for food sovereignty and 17 questions from four indicators for food security. Each indicator was defined by several variables with a question aligned with it. Table 3 lists the indicators and variables as well as corresponding shortened variable names.

Additional files 1 and 2 uses these shortened variables’ names; some of the variables were excluded during the Delphi expert consultation and thus the shortened variables’ names are not sequential.

Statistical analysis

Principal Component Analysis (PCA) is a method to reduce data dimensionality and categorize the variables by their contributions based on the responders’ opinions [38]. PCA was employed in this analysis to perform data reduction by explaining the variance across a large number of measured variables into fewer broader constructs, or components. First components extracted explain the largest proportion of total variance across the input variables, and eigenvalues associated with these provide a measure of effectiveness of the observed dimensional reduction. Successive (e.g., second, third) components are extracted such that they are statistically uncorrelated

Table 2 Definitions and indicators of food security and food sovereignty

Food Security	Food Sovereignty
<p>Definition Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences in order to lead a healthy and active life [36]</p> <p>Indicators</p> <ol style="list-style-type: none"> 1. Availability <ul style="list-style-type: none"> • Import and export markets • Financing and banking • Investment in irrigation • Road networks and port • Soil fertility and water usage • Annual rice production • Knowledge and implementation of new practices (GMO, hybrid seeds) 2. Accessibility <ul style="list-style-type: none"> • Food supply value chain for vulnerable majority • Access to the updated information about rice production • Increasing revenue for small-scale producers • Access to the natural resources such as land and water 3. Utility <ul style="list-style-type: none"> • Improving food security policies to improve food patterns and cultural patterns (Family-oriented farming and labor, Inheritance of land) • Teaching the correct use of natural resources and adapting to climate change • Improving consumption patterns through a variety of training programs 4. Quality <ul style="list-style-type: none"> • Training new cultivation practices for rice seeds • Mechanisms like quality control Lab for monitoring • Accessing to the healthy and notorious food 	<p>Definition Food sovereignty is the right of people to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems [37]</p> <p>Indicators</p> <ol style="list-style-type: none"> 1. Localizes food system <ul style="list-style-type: none"> • Improving access to import markets • Improving access to export markets • Determining guaranteed purchase price • Strengthening access for financial assistance • Improving the import and export policies of rice crops 2. Builds Knowledge and skills <ul style="list-style-type: none"> • Using proper technology in planting, preservation and harvesting • Increasing human capital through training an expert force • Organizing various local classes, such as development classes, etc • Strengthening the proper use of indigenous and local knowledge 3. Puts control locally <ul style="list-style-type: none"> • Ensuring that the voices of small-scale producers are heard by the authorities • Promoting local governance and decentralization in rural management programs • Adopting appropriate rules to reduce conflicts on land • Integrating land under rice growth 4. Values for food providers <ul style="list-style-type: none"> • Improving gender equality through empowerment of rural women as a basic work force (rice growers) • Increasing Flexibility in Vulnerable population through increasing awareness • Empowering small-scale producers to participate in the policymaking 5. Right to food <ul style="list-style-type: none"> • Policies to support food production (pricing policies) • Food satisfaction needs and cultural preferences 6. Works with nature <ul style="list-style-type: none"> • Strengthening the access of rice growers to water resources through optimal management • Managing and conserving resources, especially water resources, for sustainable livelihoods

with prior components and explain successively less variance. The method employed for choosing the number of components to select in each PCA was the “Kaiser criterion”, which retains only PCs that have an eigenvalue greater than 1.

In this study, PCA was applied to find correlation as well as dependency among indicators and their items, according to rice growers’ opinions with respect to the role of rural organizations. PCA was performed within each indicator area (i.e., ‘Localize food systems’, ‘Values for food providers’, ‘Puts control locally’, etc.), and the first component scores were extracted to establish what the authors refer to as *focused indicators*. Contextual interpretations of these focused indicators are provided in the Results section. To analyze the association between the focused indicators, partial correlation analysis was performed (correlating all possible pairs of focused indicators within a pillar, adjusting for other focused indicators within the pillar). Significance levels of 0.05 were used

to determine significance. All analyses were performed using R version 4.0.2 [39].

Results and discussion

Food sovereignty

Results for Food Sovereignty and its six indicators are shown in Table 4 based on the eigenvalues for each first principal component, and the percent of total variance explained for each first component is provided for each indicator. The first indicator, ‘Localize Food Systems’, with maximum eigenvalue of 3.48 explained 65.6% of total variance for this dimension and the second, ‘Builds Knowledge and Skills’, has an eigenvalue of 3.14, with 69.6% of total variance. The other indicators with the eigenvalues and total variances in order are: Local Control (eigenvalue of 2.89) with 60.7% of total variance; Values for Food Providers (1.81) with 73.3% of total variance; Works with Nature (1.67) with 81.6% of total variance; and Right to Food (1.12) with 67.9% of total variance. As

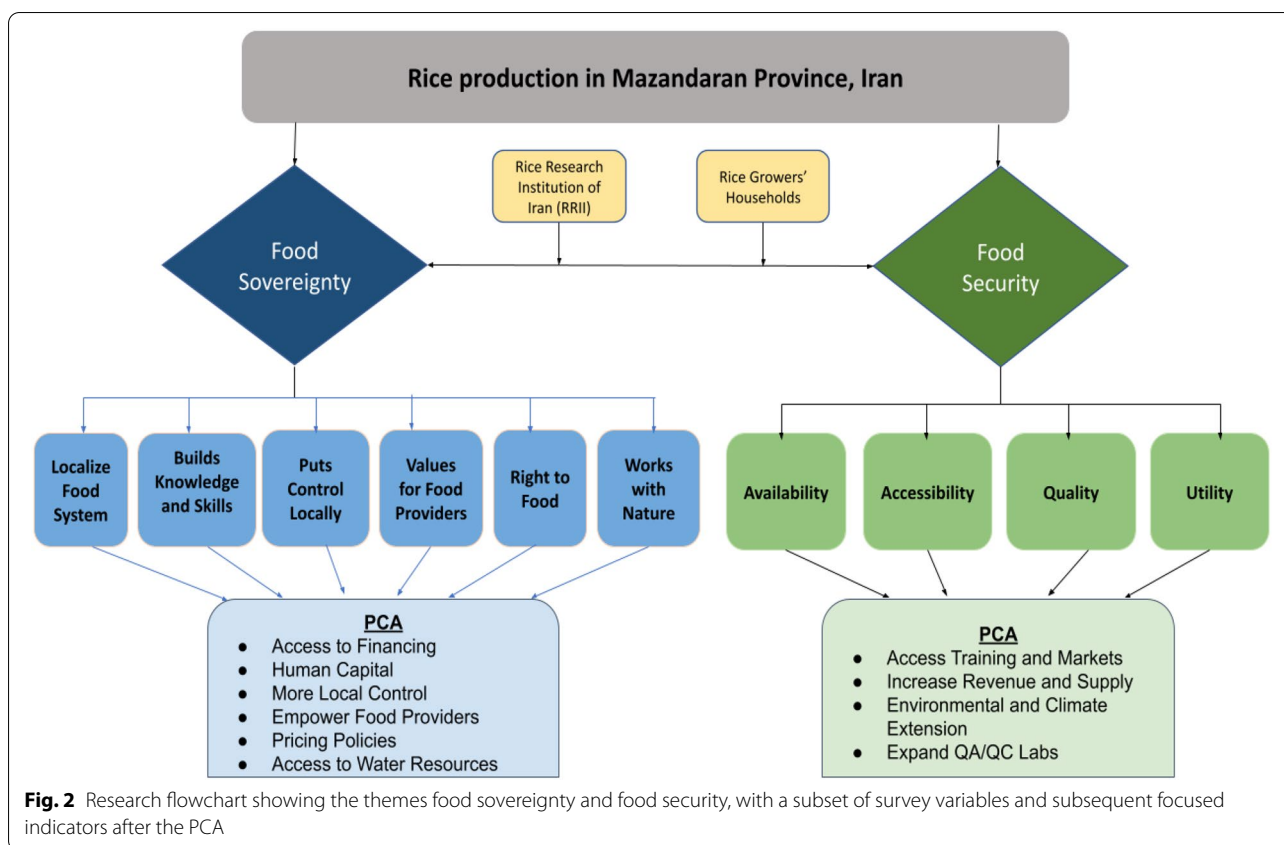


Table 4 shows, all eigenvalues are greater than 1 and the total variance of the first component for all indicators are greater than 60%, an acceptable amount to keep the first component to explain areas of each indicator.

A PCA was applied to reduce and group the 20 items contributing to define the six indicators of food sovereignty. For each indicator, the item or items that had been heavily weighted were extracted considering rice farmers' opinions in surveys (Table 5). 'Guaranteed Purchase Price' (defined as the government's proposed price for buying rice from small-scale rice growers) with 30.7% of the total variance and 'Strengthening Access for Financial Assistance' through rural institutions with 28.1% of the total variance. These components were grouped into a focused indicator named 'Access to financing'. The indicator 'Builds Knowledge and Skills' originally tested four variables, with the first two components 'Increasing Human Capital' through training an expert workforce with 23.7% and 'Organizing Various Local Classes', such as development classes for local rice farmers, with 22.6% of the total variance, resulted in the focused indicator 'Human capital'. 'Hearing the Small-Scale Producers', with 35.6% of the total variance, resulted in the focused indicator named 'More local control'. The focused indicator "Empower Food Providers" is almost equally explained

by 'Empowering Small-scale producers to Participate in Policy-Making' (37.3% of total variance) and 'Improving Gender Equality' (35.1% of total variance) through empowerment of rural women as a basic workforce for rice. Both 'Access to Water Resources' and 'Pricing Policies' focused indicators were explained by a single component, including 'Strengthening Access of Rice Growers to Water Resources and Optimal Management" with 62.1% of total variance and 'Improving Product Pricing Policies' with 96.3% of total variance, respectively.

The focused indicators represent the important real-world needs identified by rice growers to reach food sovereignty (Table 5). 'Access to financing' indicates desire for financial assistance provided by the government for rice growers, with resources administered through innovative rural institutions (e.g. Rice Research Institute of Iran) and rural cooperatives as facilitators. 'Human capital' focused indicator reflects the desire for local training available to rice farmers. More control at the local-level means management of rice production such that the voices and needs of the small-scale producers are heard by authorities. 'Empowering food providers' indicates a need for input into policy decisions by the growers themselves, as well as development aimed especially at women as a major workforce in rice production. Strengthening

Table 3 List of variables and corresponding questions

Pillars	Indicators	Shortened variable names	Questions Questionnaire of close-ended questions with Likert scale from very high to very low
Food Sovereignty	Localize food systems	Eco1	Improving access to import markets
		Eco2	Improving access to export markets
		Eco3	Determining guaranteed purchase price
		Eco4	Strengthening access for financial assistance
		Political9	Improving the import and export policies of rice crops
	Builds knowledge and skills	Edu3	Increasing human capital
		Edu5	Organizing various local classe
		Edu6	Strengthening the proper use of local knowledge
	Put control locally	Tech2	Using proper technology in planting, preservation and harvesting
		Political1	Authorities hearing producers' voice
		Political2	Promoting local governance and decentralization
Values for food providers	Political3	Integrating land under rice growth	
	Political4	Adopting appropriate rules to reduce conflicts on land	
	Social2	Empowering small-scale producers	
Works with nature	Social4	Improving gender equality	
	Social9	Increasing flexibility in vulnerable populations	
	Sus1	Managing and conserving resources, especially water resources	
Right to food	Infra6	Strengthening the access to water resources and optimal management	
	Political6	Improving product pricing policies	
Food Security	Availability	Utility	Food satisfaction needs and cultural preferences
		Available1	Improving and restoring resources (Land and Water)
		Available2	Investing in new and consistent technologies
		Available3	Investing in rural markets
		Available4	Investing in infrastructure in villages
		Available5	Improving access to credit and savings systems
		Available6	Improving research and innovation in agriculture
	Available7	Possibly improving food production in rural areas	
	Accessibility	Access3	Strengthening access to knowledge and information
		Access5	Improving access to natural resources (land, water)
		Access6	Increasing revenue for small-scale producers
		Access7	Improving the supply of food for the vulnerable majority
	Utility	Utility1	Improving food patterns and cultural patterns
		Utility2	Teaching correct use of natural resources and adapting to climate change
		Access1	Improving consumption patterns through training programs
	Quality	Safety1	Improving the quality of rice grains
		Safety2	Using mechanisms to ensure the health of the food
Safety4		Accessing healthy and nutritious food	

Table 4 First principal component extractions for each indicator of food sovereignty

Indicators	Eigenvalue	% Total variance explained
Localize food systems	3.48	65.6
Builds knowledge and skills	3.14	69.6
Local control	2.89	60.7
Values for food providers	1.81	73.3
Works with Nature	1.67	81.6
Right to food	1.12	67.9

access of rice growers to water resources and optimal management is a common theme, since water is a crucial resource in western Asia. Pricing policies as our last

focused indicator shows the importance of food pricing policies in food sovereignty.

Partial correlations (with p values)

Food sovereignty first principal components Next, we found the correlation between focused indicators through partial correlation and p value (Table 6). Component weight represents the correlation between the component and variable. To find the correlation between the focused indicators, partial correlation has been used. Results for the focused indicators of food sovereignty are shown in Table 6. Some of them are moderately correlated such as 'Access to financing' and 'Empowering food providers' and 'Access to water resources' as well as 'More local control' and 'pricing policies' and 'human capital' with p value

Table 5 Focused indicators and their contributions

Focused indicators from PCA extraction	% Contributions
Access to Financing (from <i>Localize Food Systems</i>)	30.7
• Guaranteed Purchase Price	28.1
• Strengthening Access for Financial Assistance	
Human Capital (from <i>Builds Knowledge and Skills</i>)	23.7
• Increasing Human Capital	22.6
• Organizing Various Local Classes	
More Local Control (from <i>Local Control</i>)	35.6
• Hearing the Small-Scale Producers' Voice	
Empower Food Providers (from <i>Values for Food Providers</i>)	37.3
• Empowering Small-scale Producers to Participate in Policy-Making	35.1
• Improving Gender Equality	
Access to Water Resources (from <i>Works with Nature</i>)	62.1
• Strengthening Access of Rice Growers to Water Resources and Optimal Management	
Pricing Policies (from <i>Right to Food</i>)	96.3
• Improving Product Pricing Policies	

Table 6 Partial correlation with P-value for food sovereignty variables and resulting focused indicators

	Empower food providers	More local control	Pricing policies	Human capital	Access to water resources
Access to financing	0.459 (0.001***)	0.168 (0.064)	0.093 (0.307)	0.056 (0.541)	0.482 (0.001***)
Empower food providers		0.128 (0.160)	0.093 (0.308)	0.226 (0.012*)	0.124 (0.174)
More local control			0.339 (0.001***)	0.463 (0.001***)	0.018 (0.848)
Pricing policies				0.184 (0.042*)	0.270 (0.003***)
Human capital					0.243 (0.007***)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

lower than 0.001 and some others are correlated with greater p value. All these focused indicators and partial correlations are explained further.

Previous research has shown that political commitment, effective institutions, and a systematic approach of innovation and adequate investments can improve the living conditions of smallholder farmers [40]. Our results of partial correlation and food sovereignty's principal components show that 'Access to financing' was a first focused indicator extracted (Table 5) for food sovereignty and was significantly related to 'Empower food providers' and 'Access to water resources' indicators (Table 6). Innovative rural institutions can create a linkage between rice growers and policy-makers. For example, the Ministry of Agriculture Jihad in Iran can influence policies related to guaranteed purchase price of rice, so farmers would be able to manage their production in a more economically sustainable way. Policies at the local level may need to prioritise small-scale households, since more than 75% of

rice in Mazandaran Province is produced in smallholder fields, therefore, facilitating access to financial assistance, such as credits and loans for inputs (seeds, fertilizers, pesticides, etc.) [23], which has likely been reflected in the results of the PCA.

'Empowering food providers' represent the rice farmers' desired participation in policy-making. It also correlates with 'Human capital'. Since women are the main workforce in rice production, food providers can be empowered by investing in human capital for better access to knowledge and information through training and building capacity [41]. Women's empowerment is a key means of achieving gender equality [42, 43, 44]. Transforming food systems to be more inclusive requires enabling women to participate and benefit equally, and empowering them to make strategic life choices [26, 45]. It involves women having the capacity to determine and shape their own lives and contribute—equally with men—in shaping the lives of their families, communities

and societies [46]. Women are important agricultural producers in rural areas, including in northern Iran, and have made a remarkable contribution in rice farming [47]. The UN Food and Agriculture Organization argues that women are the backbone of the rural economy in the developing world given the key role they play in contributing towards food security [30]. Doss et al. [48] analyzed four gender statements—including “(1) 70% of the world’s poor are women, (2) Women produce 60 to 80% of the world’s food; (3) Women own 1% of the world’s land; and (4) Women are better stewards of the environment”—and found that some of these statements are actually grounded in real-world data. Our study findings align with statements (2) and (3) from Doss et al. [48] in the context of rice growers in Iran. Therefore, improving gender equality by empowering women and their involvement in production and management activities could have serious implications for policy and practice, especially in terms of productivity [42]. Future work will need to focus on the importance of women’s contribution to rice growing in northern Iran, including explicit policies and opportunities to improve food security and food sovereignty by empowering women. However, the farmers surveyed in this research did not consider the role of women and future work could address this directly given the results from this work indicate a relationship between empowerment and human capital. This speaks to gender imbalance and lack of women empowerment in the agricultural sector and rural communities of Iran. Can you achieve food sovereignty if a community leaves out an indicator representing at least half of the population?

Findings of Sidibé et al. [40] show that local control and decentralization of governance requires the transfer of public mandates to local communities. ‘More local control’ by local authorities, such as the rice institute, with membering farmers has a huge impact on rice production along with improving the food prices and pricing policies. Furthermore, the voices of small-scale producers, rice growers in this case, can then be heard by authorities in government and public organizations. In this regard, policy makers with innovative rural institutions’ contribution can access quantitative and qualitative information for the design and implementation of evidence-based strategies, plans and programmes related to food prices and policies [46, 49].

Public policies especially ‘Product pricing policies,’ play a determinant role in shaping the future of agricultural and food systems: they can underwrite legal frameworks to protect, respect and fulfill the Right to Food; bolster the investments made by small-scale food producers; and mobilise societal resources in support of sustainable food systems based on notions of resilience, decent work, environmental integrity and the provision of healthy

food [50]. This has correlated with ‘Human Capital’ and ‘Access to Water resources.’ Human capital development with local training classes improves rural welfare. Human capital for rural households is defined as investing in schooling, informal training and local classes, information search, technology adoption and good health [24, 51]. Once household members have obtained their human capital and the focus is on choice of occupation, hours of work, purchased-input use, wage rates, or income, one-period static agricultural household models provide a useful guide to researchers [52]. Rural organizations can develop human capital by providing access to local classes and training [10]. In addition, efficient and smart use of resources and the adoption of less water-intensive crop production systems are the present requirements to achieve sustainable food production. In addition, the sustained availability of resources, such as water [53], is ever-present. Limited water resources and population growth have caused a decline in agricultural production in some countries. Currently, this limitation is one of the most serious problems in Middle Eastern countries, especially arid and semi-arid countries [21]. Iran, with nearly 165 million hectare of land area and rainfall amounts equal to 300 mm in 67% of its territorial land, is considered as a semi-dry region in the world. Research on the historical overview of Iran’s agricultural changes and evolution illustrated the fact that the land has a remarkable role in agriculture development of the country and received considerable attention after enforcement and continuous efforts for land reform [54]. There is no large-scale, country-wide analysis quantifying the suitability of Iran’s land for agricultural use and land evaluation in Iran has been conducted only at local, small scales and based on the specific requirements of a few crops, such as wheat, rice and faba bean [55].

Rice production in Iran needs to be increased to feed a growing population, whereas water for irrigation is getting scarce [56]. Efficient application of water in agriculture is one of the most important factors in food sovereignty and food security of the country. Proper planning, management, and education in this sector would help prevent the waste of limited natural resources [21]. In this regard, innovative rural organizations can cause straightening access of small-scale farmers to optimal management in natural resources especially water with human capital development.

Support networks should be created by rural institutions in multiple rural areas [4]. Agricultural policies, which generally take into account macroeconomic interests, should pay attention to the food sovereignty of people in deprived areas at a micro level, as the development of these areas will play a major role in the development of the country in the future [57]. Results show that, not all

focused indicators derived from the surveyed indicators were significant in terms of relating amongst themselves in a real-world situation. Some indicators were more important or even more obvious to the rice growers. For example, they understood and expressed a need for accessing financial assets and investing in human capital. However, pricing policies are not controllable by small-scale rice households and so was not a designated indicator from their point of view.

Food security

Food security is recognized as a multifaceted condition of complex causality that is related to, yet distinct from, poverty and hunger [58]. Given its broad definition, food security often eludes precise measurement. This study considers there to be four indicators of household food security (Availability, Accessibility, Utility and Quality) along with 16 items to explain the indicators. Table 7 indicates that the PCA results highly explained the food security indicators and their contributions. Availability of food is the first component extracted from PCA with the eigenvalue amount of 2.63 and total variance 61.7%. Second, component is Accessibility (2.44) with 61%. The next two components are Quality (2.01) with 68.3% and Utility (1.26) with 73.1%, respectively.

The items for each indicator have been stratified based on their contributions and the highest ones are shown (Table 8). Like food sovereignty, “focused indicators” were

defined based on the importance areas of each indicator. They are showing the significance of these indicators from the rice growers’ opinions. It is important to link the food security’s indicators with actual needs of farmers. Therefore, we labeled the indicators as the focused indicators. Among seven variables belonging to ‘Availability’, ‘Improving research and innovation in agriculture’ that explain the knowledge and implementation of new practices for rice production, such as GMO, hybrid seeds, etc. with 21.4% of the total variance and ‘Investing in rural markets’ with 20.2% of the total variance resulted in the focused indicator ‘Access training and markets’. Next focused indicator in Table 8 is ‘Increase Revenue and Supply’ which was best explained by “Increasing revenue for small-scale producers” with 32.6% and “Improving the supply of food for the vulnerable majority” with 30.9% of total variance, likely highlighting the rice growers’ opinions on the role of rural institutions to assist farmers. ‘Using mechanisms like quality control lab to ensure the health of the food’ with 51.7% of total variance and ‘Teaching the correct use of natural resources and adapting to climate change’ with 42.7% are extracted based on their contribution in the survey, resulting in the focused indicators of ‘Expand QA/QC labs’ and ‘Environmental and climate extension’, respectively. Therefore, the highlighted dominant of each indicator is considered as focused indicators which explain their areas that are important in this research.

Partial correlations (with p values)

Food security first principal components Partial correlation between the focused indicators is estimated based on the *p* value (Table 9). Moderately correlated and highly significant indicators (*p* value < 0.001) are ‘Access training and markets’ with ‘Increase revenues and supply’ and ‘Environmental and climate extension’. The focused indicator ‘Increase revenues and supply’ was correlated with ‘Environmental and climate extension’, perhaps indicating the rice growers’ perception that additional training will

Table 7 First principal component extractions for each indicator of food security

Indicator	Eigenvalue	% Total variance explained
Availability	2.63	61.7
Accessibility	2.44	61
Quality	2.01	68.3
Utility	1.26	73.1

Table 8 Focused indicators and their contributions

PCs and extracted items	% Contributions
Access Training and Markets (from <i>Availability</i>)	21.4
• Improving research and innovation in agriculture	20.2
• Investing in rural markets	
Increase Revenues and Supply (from <i>Accessibility</i>)	32.6
• Increasing revenue for small-scale producers	30.9
• Improving the supply of food for the vulnerable majority	
Expand QA/QC Labs (from <i>Quality</i>)	51.7
• Using mechanisms like quality control lab to ensure the health of the food	
Environmental and Climate Extension (from <i>Utility</i>)	42.7
• Teaching the correct use of natural resources and adapting to climate change	

Table 9 Partial correlation with *P*-value for food security variables and resulting focused indicators

	Increase revenues and supply	Environmental and climate extension	Expand QA/QC labs
Access Training and Markets	0.349 (0.001***)	0.357 (0.001***)	0.220 (0.014*)
Increase Revenues and Supply		0.308 (0.001***)	0.006 (0.951)
Environmental and Climate Extension			0.354 (0.001***)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

increase crop yields.; Finally, the ‘Environmental and climate extension’ was correlated with ‘Expand QC/QA labs’. These focused indicators have thematic overlap, including access to new seed types, perhaps linking the perception of needed testing for future rice varieties.

To explain food security at household level, classification of four indicators of food security were used. Small-scale farmers will need good products and information to use new practices [17, 59]. Innovative rural organizations and community-based farm leaders would be able to fill the role of trainers and educators as well as facilitators to access the rural markets [60]. Reliable market access boosts productivity, increases incomes and strengthens food security of rice farmers [52, 61]. It isn’t always easy to connect smallholders to markets, nor to ensure their produce meets market standards. This could be promoted using some mechanisms such as Quality Control labs to make sure the quality of seeds and paddy meet the market standards [62]. Unequal distributions of power also mean small producers can earn significantly less than other actors, such as larger processors, retailers and exporters [63]. Therefore, the rural organizations could accelerate better access to domestic and international markets, this, therefore, allows small producers to reliably sell more products, with better quality and at higher prices to increase their revenues and supply [4]. Therefore, adapting food systems both to enhance food security for the poor and vulnerable and to prevent future negative impacts from climate change will require attention to more than just agricultural production and it needs attention to teaching the correct use of natural resources especially water resources and adapting to climate change.

Conclusions

This research shows that from the perspective of the surveyed rice growers in northern Iran, four main indicators that relate to investment and resources were the most significant: capital, markets, credit, and knowledge. Capital in this context means access to land and/or land tenure, including access to the land, and renewable resources, such as water for irrigation. Markets are more complex,

with a need for adequate infrastructure (everything from roads to crop storage to shipping), communication networks that provide farmers with access to the latest prices, and the ability to meet the supply standards in supermarkets. Credit improves access to new practices, or even access to basic inputs, such as fertilizers. Rice growers wanted more knowledge, such as agricultural extension and transformative research to improve their production. The results of this study demonstrate the desire in Northern Iran for the role of innovative rural organizations as vital linkages between rice farmers and the public sector (i.e., Ministry of Agriculture Jihad). Policies at the local-level may need to prioritize small-scale households by facilitating access to financial assistance, such as credit and loans for inputs (seeds, fertilizers, pesticides, etc.) [23]. For the food sovereignty results of this research, six focused indicators were extracted from PCA, including access to financing, human capital, more local control, empowering food providers, access to water resources, and pricing policies that were noted by rice growers. Four focused food security indicators from the rice growers’ perspective were extracted from PCA, including access training and markets, increasing revenue and supply, expanding QA/QC labs, and environmental and climate extension.

Agricultural policies to combat food insecurity often do not take into account the views of the local agricultural producers or how local agricultural production links to household food insecurity. Fiscal policies could promote nutritional knowledge for household members while also supporting households to meet their nutritional needs and local producers to sell their agricultural products. Priority for middle and low socioeconomic groups is needed, to encompass struggling populations but also most rice farmers.

This study shows that women are important agricultural producers in rural areas of Iran and they are the backbone of the rural economy given the key role they play in food security. Particularly, they are responsible for about 60% to 80% of food production in developing countries and are the main custodians of knowledge regarding crop varieties [48, 64]. Therefore, future work will need

to focus on the importance of women's contribution to rice growing in northern Iran by empowering women through improving their access to resources and training.

Promoting food security in remote and rural areas that include largely Indigenous populations needs to consider food sovereignty [65]. The food sovereignty movement was La Via Campesina's response to liberalisation of free trade and has been taken up widely by communities across the Global South [66]. The *Declaration of Nyeleni* states that food sovereignty is the right of peoples to healthy and culturally appropriate food, produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems [8]. The movement encourages small-scale food producers to grow and distribute food within local food systems, the polar opposite mindset of multinational corporations [67]. Food production in Iran is highly centralized and relies on governmental mandates and financing, which this study shows is not the perceived improvements by the rice-grower's themselves. Future work should focus on the intersections of food sovereignty and food security.

Supplementary Information

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Additional file 1. Food Sovereignty PCA Summary - percents of contributions of dimension 1 and dimension 2 for each indicator in Food Sovereignty.

Additional file 2. Food Security PCA Summary - percents of contributions of dimension 1 and dimension 2 for each indicator in Food Security.

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Author contributions

All authors contributed to the study conception and design. Data collection was conducted by Maryam Zamanialaei and the material preparation and data analysis were performed by MZ, JM, MH, and JF. The first draft of the manuscript was written by MZ and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

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Declarations

Ethics approval and consent to participate

All study procedures and ethical considerations for human subjects were approved by Islamic Azad University, Iran and Rice Research Institute of Iran.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All study participants remain anonymous with private and culturally sensitive information protected. Analysis performed for this manuscript was completed using the anonymous database, with no access to names or locations of individuals interviewed and/or surveyed. Verbal informed consent was obtained prior to the interview.

Consent for publication

The participant has consented to the submission of the case report to the journal.

Competing interests

The authors declare they have no conflict of interest.

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