



Review Article

Food-energy-water nexus in Iran over the last two centuries: A food secure future?

Farshad Amiraslani^{a,*}, Deirdre Dragovich^b^a School of Geography & Environmental Sciences, Faculty of Life & Health Sciences, Ulster University, Coleraine BT52 1SA, UK^b School of Geosciences, University of Sydney, Sydney, NSW 2006, Australia

ARTICLE INFO

Key words:

Agriculture
Energy
Food provision
200-year
Iran

ABSTRACT

Over the past two centuries, Iranian agricultural policy and practice have been developed dramatically, mostly in response to population growth, gradual improvements in technology and science, several revolutions, one major war and recent international sanctions. Until the mid-20th Century, Iran was an agrarian society, barely distinguishable from other countries in the region. It then shifted to an industrial society supported by oil, with agriculture lagging, but since then, major agricultural policy shifts have occurred. First, a series of inappropriate national laws regarding land tenure converted large holdings into small pieces of low-yielding lands. Then, the Islamic Revolution occurred in 1978, followed by a subsequent eight-year war with Iraq, which shook the country's economy and left many farms devastated and abandoned. At that point, the food supply chain and provision were in chaos. The Government prioritised food self-sufficiency by heavily subsidising farm inputs and investment into water management, power plants and food processing plants. By the mid-2000s, despite the pressures of rapid population growth and severe drought conditions, the country became largely self-sufficient in major food crops. Government subsidies rose to unsustainable levels, and a large amount of food was being wasted throughout the food chain. In response, the Government removed subsidies from the food and energy sectors and in 2010 provided financial support for those on low incomes. Recent geopolitical disruptors have contributed further to an unstable food-energy-water nexus.

1. Introduction

Iran's vast plateau is bordered by high mountains, notably the Zagros (west) and Alborz (north), resembling a vast saucer [1]. Most of the interior plateau consists of dryland areas where agricultural activities have been in place for millennia; inland rivers have attracted populations and cities have flourished. As a dryland country with a long history of cultivation, Iran is regarded as one of the oldest historical sites of agriculture on the planet. Historically, the country was an agrarian-based society until the early twentieth century, after which agriculture changed only slowly up to the 1960s.

Agriculture commenced tens of thousands of years ago in western parts of Iran and gradually expanded outwards. Archaeological evidence suggests that a movement from the southern Levant (the Eastern Mediterranean and Western Asia) to the rest of the Near East and to the Zagros–Taurus Mountains (West Iran) started around 12,000 B.P when agricultural communities were established [2]. Gradually, “the initial transition from an earlier dependence on hunting and gathering to an incipient experimentation leading to the domestication of both animals and plants” occurred about 7000 BC [3, p.2]. The land and sea routes of

ancient Iran were used for regional and international trade (exports and imports), notably as part of the well-known Silk Road. The Persian Gulf was a viable sea link for millennia (e.g., [3]). The country's remarkable geographical position could have made it possible to link Far East Asia to Europe via land routes. Nevertheless, domestic challenges, such as the lack of roads and absence of a central government, prevented this locational advantage from being realised. As early as 5000 BC, excavations revealed large buildings for the distribution of surplus grain in Tepe Yahya (Kerman province-Iran) [3]. Though no reliable data may exist, agricultural commodities (grains) would logically have contributed to traded items, along with pottery and precious stones.

Writing on any aspect of Iran's economic history is difficult given the paucity of reliable sources. Moreover, like other inter-disciplinary topics, a nation's energy, water and food issues cannot be contemplated without including their association with economic, political and social factors. Based on the existing literature, this paper reviews historical trends of agriculture and food production in relation to water and energy in Iran over the course of a 200-year period, with most emphasis being placed on the recent 40 years due to the availability of more reliable sources.

* Corresponding author.

E-mail address: f.amiraslani@ulster.ac.uk (F. Amiraslani).

The pivotal argument of the paper is the important role of the evolution of a more centralised administration, from an almost non-existent central government in the nineteenth century. The role of Iranian rulers/governments/authorities has been inconsistent, hasty, and mostly unplanned with varied strategies and approaches, from inattentiveness to intervention to investment. But one key issue has not changed or has even become worse: drought. This climatic parameter has shaped and impacted every aspect of crop production in the country in the past and still looms large. Further economic and social changes have also accompanied the emergence of oil as a new energy source that had been discovered in the early twentieth century.

This review covers major crop production and does not include livestock or fishery products. Except for a narrow zone across the southern and northern parts of the country, fisheries have never been a major income- or foodstuff-generating sector. Here, we review a long period of food administration in an oil-rich country, providing a novel case study within the food-energy-water context, illustrating how Iran has strived to meet increasing national foodstuff requirements through its land and water resources. We explore how the country's agricultural and food policies have changed with particular reference to the last forty years, a period of major social and ideological upheaval (the occurrence of the Islamic Revolution, the Iran-Iraq war and unprecedented population growth), covering the dramatic policy changes in 2010 when Iran became the first major oil-exporting state to enact large subsidy cuts for food and energy [4]. Similar to all countries in the region, irrespective of their social, political and economic differences, Iran faces climate change and water shortages which test the resilience of its agricultural system.

2. A chronological overview of the agriculture-energy-water nexus in Iran

2.1. Nineteenth century: No plan for water and energy

During the nineteenth century, Iran (called 'Persia' until 1935) was in a chaotic situation in every aspect of life: relative economic stagnation and delayed development and progress (e.g., no roads at all until the very late 19th century); the absence of a modern banking system; and gradual population growth (from 5 to 10 million) [5]. This century was also characterised by an increased penetration of foreign goods, a rapid depreciation of the currency, and a rise in prices including those for agricultural products, increased private investment in land, and the growth of significant private land ownership [5,6]. The chaotic situation was systemic and not restricted to rural areas only, as lower classes constituted over 60% of the urban population [7].

The country had no national economic plan or stabilised revenues, leading scholars to call the then Persia an "economic wasteland, sucked dry by a corrupt political system and foreign exploitation" [8, p.36]. Desperate and inept rulers did not hesitate to survive and gain financial benefit at any cost, including selling crown lands or sub-renting them to new landlords [5, p.68]. From a technological perspective, agriculture was primitive, utilising ox-drawn ploughs and hand-weeding [9]. The agricultural and food production systems suffered from the chaotic national situation, characterised by low technical specialisation, productivity and investment [7]. During this century, especially in the second half, droughts and plant diseases affected agricultural production, leading to a major famine in the country (Table 1). No energy sources other than fuelwood were available and used.

In addition to wheat and a limited number of other plant species, two specific cash crops (cotton and opium) were significant. "Cotton became Iran's chief export, responding primarily to the demands of the Russian market" [5, p.69]. Opium also received attention after the mid-19th century due to the growing markets outside Iran [9]. This cash crop was cultivated in the central dryland provinces (Isfahan, Yazd, Fars, Kerman) and shipped from southern ports of Iran to the export markets of China and European countries, mainly to London [9]. While

a prominent Iran studies scholar [5] mentioned the cultivation of opium on former wheat lands combined with a series of droughts as culprits for the terrible famine of 1871–72, others believed that the land area allocated for opium was not sufficiently sizeable to have caused this famine [10]. Such widespread lack of food jeopardised the health and life of all within the population regardless of age but especially the poor and children [11], while diseases such as smallpox, measles, and diphtheria were also prevalent.

Of the four specific inputs needed for agricultural production – land, water, energy, and labour – land and labour were not problematic at that time. Poor transportation, low literacy, and inadequate services caused most of the population (85–90%) to be involved in conventional agriculture. Water, however, has always been an impediment to agricultural development and production in Iran. The geography and climate of Iran are typical of countries dominated by arid and semi-arid areas with inadequate precipitation and frequent drought cycles. For centuries, qanats were a common method of providing and distributing water for irrigation. Water resources were limited not only in dryland provinces but also in other areas having relatively high precipitation, with the water situation being much worse in earlier times due to the lack of water storages and transfer infrastructure. For instance, in 1860 it was reported that water was scarce in Tabriz and its neighbourhood [12], despite the city's location in the northwest of Iran, a region with an annual average of over 300 mm rainfall that enables more reliable arable cropping.

Overall, there was no plan for water and energy. The predominant energy source was based on woodfuel. Natural forests were used as monetary vehicles for the bankrupt country to finance the expenses of corrupt rulers or to provide woodfuel for the ordinary people. For instance, Consul Churchill reported in 1876 that 200,000 trees were hewn down in Gilan and Mazandran (northern provinces) in the year before [12].

2.2. Twentieth century: A transforming period for energy and water

The twentieth century was a period of transformation in the history of 'Persia', which had been renamed 'Iran' in 1935. This century is distinguished from other historical periods in terms of social, political, and economic changes [13]. Socially, the country experienced an unprecedented population boom of up to eight-fold by the end of the century [13]. Economically, oil exploration and industrialisation created an opportunity for a series of centralised governments, with ambitious developmental plans, to invest in infrastructure, diversify the lifestyle and improve education and health. Politically, the country experienced its first written Constitution Law and a Parliament, which heralded a dramatic shift in the role of people in decision-making. During the twentieth century, several governments were imposed or installed while there was one major war (the eight-year Iraq-Iran war). The war, however, had culminated with no specific outcomes except for its devastating consequences.

Within the twentieth century, three eras can be identified: the period up to 1925, the years between 1925 and 1978, and the post-1978 period. These eras are defined by two major government and thus policy changes: in 1925 the Pahlavi regime took power, and 1978 marked the Islamic Revolution and the inception of the modern-day Islamic Republic of Iran.

2.2.1. Up to 1925

No improvement was seen in the country, especially on the agricultural side, in regard to energy and water (Table 2). Although farming methods were primitive, irrigation was undertaken through the traditional interconnected underground system of water canals (qanats). The first agricultural machinery was imported in 1902–03, but there was a shortage of fertilizer or animal manure due to the lack of capital and infrastructure, resulting in an "archipelago of small islands of cultivation surrounded by enormous seas of desert" [9, p. 142].

On the political landscape, though, a particularly critical change was highlighted by the Constitutional Revolution. During the past millennia

Table 1
Temporal milestones in the history of agriculture and associated events and consequences in Persia during the second half of the 19th century.

Timeframe	Event (years)	Consequences	Source
1860s	The silkworm disease (1864–65)	Destroyed the Iranian silk industry	[9]
	'The cotton famine' (1861–65)	Rise in price of cotton (up to 8 times)	[10]
	Droughts (1869–72)	Starvation and political discontent	[7]
	Considerable increase in opium cultivation and production (1860s)		[10]
1870–71	The Great Famine	1.5 million deaths (20–25% of population); mass migration of refugees to the northern provinces; cholera outbreaks	[10]
1890s	Reappearance of Persian carpets as an export industry; introduction of new American cotton varieties with higher yields; export of opium	Injection of European capital into the economy; possible impact of opium cultivation on the famine (1871–72)	[7]

Table 2
Major agricultural periods in Iran between 1925 and 1977

Period	Influencing factors at the national level ¹	Impacts on agriculture ¹
Till 1925	<ul style="list-style-type: none"> The Constitutional revolution 	<ul style="list-style-type: none"> Importation of first agricultural machinery (1902-03) Heavily reliance on qanats for irrigation The first exploration for a new energy source (oil) Population employed in agriculture: >80% by the early 20th century
1925–1978	<ul style="list-style-type: none"> Start of modernization in the country (1930s) World War II and the military invasion of Iran (1941-5) Formation of Planning Organization Commencement of dam construction: 1950s Industrialization and urbanization at large scale Population (1960): 23 million Nationalization of water sources: 1968 	<ul style="list-style-type: none"> Land Reform Law Establishment of agri-businesses and agricultural cooperatives Increase in application of agricultural mechanization and pesticides Population employed in agriculture: 46% (year 1966)

¹ [7,9,13,15–19]; Issawi (cited by [5])

of Persia's evolution as a territory, the country had experienced various revolutions and monarchy changes [14]. However, the constitutional revolution of 1906, aimed at "a new freedom ... being created and a corrupt tyranny destroyed" [8, p. 36], was an historical turning point. It could bring hope to ordinary people that their lives would alter for the better and their suffering would be alleviated. As one possible outcome of the Constitutional Revolution, investment in agriculture became feasible due to the greater security of land ownership, though many peasants were transformed into landless labourers [12]. The Constitution also strengthened the control of the central government to take steps necessary for ensuring food supply [7].

After suffering the first devastating famine in 1870–71, the country faced another famine caused by World War I [5]. Overall, the country's poverty, economic problems, corruption and many other shortcomings [14] formed "the basic causes of the Iranian political upheavals that characterized the period 1905–1925 and culminated in a dictatorial, centralizing, and modernizing government" [5, p. 77].

2.2.2. The period of 1925–1978

This period started with political turmoil when a military officer, Reza Shah, ended the Qajar dynasty forever and established the Pahlavi regime. The backward situation of Persia needed a diverse range of developments which were practically impossible to achieve given the scale of poverty, and problems relating to education, infrastructure, and health. Ironically, a tough and illiterate militia man commenced a series of ambitious plans copied mainly from Germany and Turkey, in a quest to modernise the country. The construction of a cross-country north-south railroad, expansion of roads, educational reforms, and other actions were noteworthy. In terms of natural resources, the establishment of an Office to preserve the northern forests was positive, as was the setting up of the first modern university in Iran, the University of Tehran, for training skilled people in various fields. This modernisation effort became economically intolerable for the population [13], as it coincided with World War II during which Iran became home to foreign troops from 1941 to 1946. Such a local political vacuum was not helpful for the country and led to a chaotic situation [13]. In the 1940s, agriculture

still had very primitive technical capacities and suffered from a lack of appropriate water supplies, affecting 35% of what was then classified as irrigated land [20].

Once the nationalised oil industry was established and revenues rose, a series of developmental plans were commenced [13]. The period 1953–1979 in Iran has been described as 'economic growth under autocracy' [13], when there was an unprecedented shift in the country from an agriculture- to an industry-based economy [13] associated with rapid industrialization and population increase [21]. Its characteristics included rising oil exports, foreign aid, support for the private sector, increased oil revenues, a job market shifting from an agrarian base toward industry and services, and improvements in infrastructure [13].

Growth of the agricultural sector lagged behind that of the developing economy. The decrease of agriculture in GNP in 1962–63 was an indicator of the country's general recession as a result of a balance of payments crisis [13]; and the declining trend of agricultural production in 1964–65 can be attributed to a failed land reform policy to reallocate agricultural land away from large landlords [13]. Introduction of the 'Land Reform Law' was intended to address land tenure issues in rural areas by breaking up large estates and redistributing land to the peasants [22], with the main goal being "the creation of a class of independent peasant proprietors who could serve as the catalyst for Iran's agricultural development" [23, p.16]. This Law was, however, unsuccessful in achieving its targeted objectives (e.g., [23,24]). The increase in population and associated food consumption during the 1970s brought into question the capacity of Iran to provide food security for its citizens [25].

2.2.3. The period 1978 onwards

The Islamic Revolution of 1978, an unprecedented surge in population and the devastating 8-year Iran-Iraq war shook the country's macro- and micro-economy. The newly established revolutionary government was not able to tackle domestic challenges; the country's infrastructure, lands and buildings were destroyed, and there was financial disorder and social unrest. The situation was especially serious in agriculture. Many farms and orchards were war-torn and devastated, arable lands

Table 3
The self-sufficiency rate in certain strategic food crops in Iran between 1989 and 2009 (%).

Crop/Year	1989	1993	1999	2005	2009
Wheat	52.4	82.1	58.5	99.4	72.7
Rice	60.3	57.6	59.9	63.0	53
Potato	100	100	100	104.9	108.3

Source: [33].

were left unattended, and many farmers had migrated to other safe areas or cities. Food supply and logistics were in chaos and the government had to launch a new policy to ration food, most of which was being imported.

After the war (1988), the government gradually initiated wide-ranging developmental activities, especially in rural areas (e.g., [26]). During the 1990s, great national efforts were made to reconstruct or develop new rural infrastructure including water systems, electricity lines, and educational and health centres. Agriculture became a key element for Iran's post-revolutionary policymakers, with 'food self-sufficiency' prioritised. A marked expansion of mono-cropping and incentive-based grain production occurred [22]. Farms were given priority for reclamation and essential inputs, including seeds, seedlings and manures, were heavily subsidised. Water dams, water channels, grain silos, power plants, and food-processing plants were constructed: the number of silos increased five-fold during this period ([27]: 2 Aug 2009). The average annual growth of agriculture during 1997–2007 reached 4%, compared to less than 3% during 1963–68 [25,28], while there was an extraordinary improvement in social indicators in Iran (e.g., literacy, life expectancy). The literacy rate of less than 5% in 1900, for instance, was raised to 83% in 2006 [13].

The subsequent period from 1999 has been hugely challenging, with population growth, social change, international sanctions, lack of infrastructure, poor marketing and harsh climatic conditions. The latter included the worst drought for 30 years in 1999–2000 which caused agricultural losses of 2.8 million tons of wheat and 280,000 tons of barley and resulted in a majority of the rural population migrating to the cities [29]. Thirty-seven million people were affected with an estimated US\$3.3 billion in losses [30].

Yet the country has become largely self-sufficient in many strategic crops (Table 3), achieving an overall 99.4% self-sufficiency in food in 2005, which was celebrated nationally. Despite continuing variability in annual production levels, the agricultural sector now provided a platform for food security and jobs. Agricultural products and carpets constituted the major non-oil export commodities from Iran employing 23.5% of the workforce and contributing 14% of the country's GDP ([31]: 24 Jan 2009). Agricultural research in Iran increased during the 1990s (the so-called 'nation-building' period), in line with an increase in the number of agricultural university students. The research effort was oriented mostly towards the effects of agriculture on the environment, the optimization of agricultural practices, the economic viability of agricultural enterprises, and the assessment of agricultural machinery, absorbing nearly a quarter of total public research funds in the country (23% in 2004) [32].

Since 1989, six Five Year Development Plans (FYDPs) have been implemented. Although there has not been a comprehensive study to measure their overall success, it seems that many policies have not been implemented fully. For instance, some funds and subsidies have been allocated for the expansion of pressurized irrigation in all FYDPs, but informal reports suggest that implementation is still behind the proposed schedule and scale. Moreover, agricultural projects have not been successful in attracting foreign investment. According to the Organization for Investment Economic and Technical Assistance of Iran (OIETAI), a total of US\$37.7 billion was approved for foreign investment between 1993 and 2009 in Iran [34]. Overall, 547 projects in the 8 major groups,

of which 'agriculture' was one, were implemented. However, only 10 out of 547 projects (less than 2%) were in the field of agriculture, farming, horticulture and poultry during this 17-year period, attracting only 0.06% of the capital invested. Even the 8 projects in the field of 'water, electricity and gas' absorbed only 14% of all foreign investment in Iran [34].

Figure 1 illustrates population growth (Fig. 1A), the national output of agricultural products (Fig. 1B), and the per capita production (Fig. 1C) in Iran over the 42 years of 1978–2020. Total output shows an upward trend (Fig. 1B) even though the country has encountered national (droughts), regional (the Iran-Iraq war) and international (financial disruptions) issues since 1978. In addition to the Iran-Iraq war and associated problems in agricultural practices, Iran experienced unprecedented population growth and frequent droughts during the 1980s. However, after the 1980s, the annual per capita production depicts values above or close to the 42-year average per capita output (Fig. 1C).

For several reasons, including subsidization, financial disruption and entrepreneurship, the post-1978 period represents a distinct break from past policies related to promoting food security and the sustainability of agriculture in the country. These reasons are discussed below.

Subsidization. Over recent decades, the heavy costs of food and energy subsidies in Iran have caused problems in terms of domestic consumption, production and trade. There was a 22-fold increase in the cost of subsidies paid by the government during the 1973–2006 period [36], while unofficial reports suggested that a million tons of bread were wasted due to inappropriate baking, mishandling of wheat flour during processing, distribution and transport, and over-purchase of bread by consumers [37]. This wastage may have been equal to the level of imported wheat in some years. Accordingly, at the end of 2010, the Government took the bold step of removing subsidies from the food and energy sectors. The essence of this national plan was to gradually remove general subsidies while targeting monthly cash payments to low-income and deprived people as compensation for loss of subsidies. The preliminary aim was to enhance productivity, social justice and equality, cash management, and investment at the national level. The new government taking office in 2013 created a 'food safety net' aimed at supplying and distributing major foodstuffs at no cost to those identified as economically vulnerable groups, including about 10 million pensioners and malnourished people ([27]: 16 May 2015). In the medium term, it was predicted that this removal of subsidies would improve Iran's economy through better domestic energy usage, increased exports, and greater overall competitiveness [38].

Financial disruption. International financial and technological sanctions imposed on the country were intensified and expanded both in terms of the scale and diversity of commodities during this period. The first US sanctions on Iran were imposed in April 1980 and intensified in 1993, 1996–2006 [13], and have escalated further since 2018. These sanctions undoubtedly adversely affected currency exchange rates, oil trading, national purchasing power, and depreciation and devaluation of national savings, as well as reducing international commodity transactions.

Entrepreneurship. The government has encouraged young graduates and entrepreneurs through offering low-interest, long-term loans to establish small-scale agri-businesses and greenhouses. Despite being criticised for diverting a proportion of loans from other investments (e.g., housing development), the scheme is thought to have encouraged many rural settlers to form local agricultural producer groups and cooperatives. For instance, the production of cucumbers, tomatoes, flowering plants, and pot plants has increased as a result of this scheme: land allocated for cucumber production in glasshouses rose from zero in previous decades to 4907 ha producing 1,095,641 tonnes in 2011, and 7539 ha producing 1,923,864 tonnes in 2020 [35]. Moreover, the government has allocated funds for supporting the expansion of pressurized irrigation systems, mechanization of farms, and infrastructure repair especially for

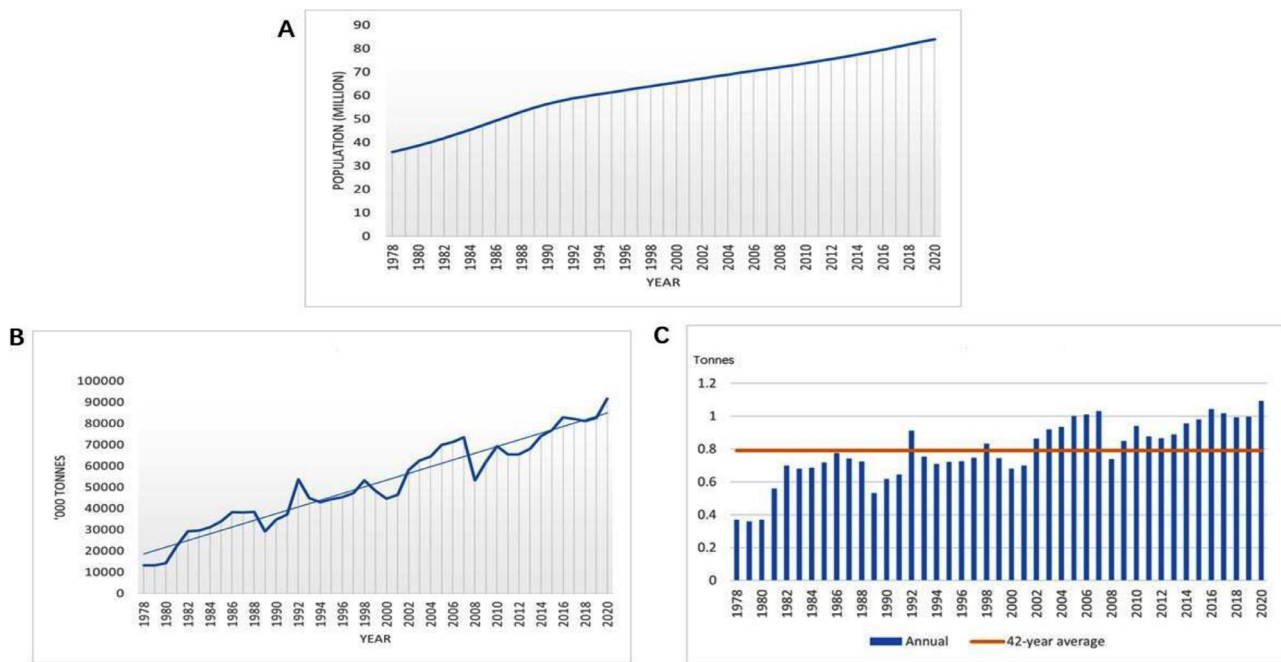


Fig. 1. A. Population growth in Iran, 1978 to 2020; B: Total agricultural output in Iran, 1978 to 2020. C. Annual per capita agricultural output in Iran, 1978 to 2020. (Agricultural production data based on MoA yearly statistical book [35]; Population data retrieved from various reliable census sources).

local agricultural cooperatives. The latest data reveal that agricultural production is undertaken on about 12 million hectares, of which almost half is used for irrigated cultivation [35]. Large investments are being made to install modern irrigation equipment, revamp old irrigation canals, develop new water canals, build farm access roads, construct drainage canals, etc. For instance, modern irrigation systems such as drip irrigation had been installed on 105,440 ha of arable land across all provinces by 2020 [35]. As a new approach to supplement water supplies, the country has been revitalising old qanats to compensate for water shortages during the dry seasons in recent years: over 306 km of such qanats were revitalised in 2020 [35]. National efforts are encouraging farmers to cultivate under glasshouses to economise on the cost of production, reduce water consumption, improve yields and facilitate pest control. Assisting the increase in agricultural output is the growth in local production of fertilizers which now accounts for 93% of national requirements [35].

In addition to these policies, the government has set up rules for incentives such as the ‘guaranteed purchase’ of strategic crops, annual crop insurance, and annual farmer insurance to support farmers by ensuring a constant flow of cash. This, in turn, can contribute to greater certainty for farmers and potentially a future with continuing and relatively more reliable agricultural production throughout the country. Despite these interventions, the trend of decline in the agricultural sector’s contribution to GDP has continued. In 1900 it is estimated that the share of agriculture in national GDP was about 65% [13]. This share has since declined sharply, with the latest World Bank dataset showing that agriculture in GDP dropped dramatically from 1960 to the mid-1970s (Fig. 2). This period coincided with an increase in the share of oil production and exports as well as expansion of the construction and service sectors [26]. Agriculture’s share regained half its losses during the 1980s and 1990s but fell again in the 2000s, emphasizing the instability in agricultural production (Fig. 1B).

2.3. Major challenges of the agricultural sector

Negative and unprecedented perturbations such as droughts or international sanctions may cause setbacks in the short- or medium-term, even though the Government has banned the cultivation of certain crops

and fruits demanding high water inputs in some regions. Moreover, the agriculture sector still faces some major challenges (Table 4). Irregular spatial and temporal rainfall distribution as well as low water efficiency have impacted adversely on water availability. Implementation of conventional cultivation and harvesting methods leads to reduced farm yields while energy consumption increases. Improper land use planning and land fragmentation are also considered a national problem as they hinder mechanisation and modernization of cultivation.

2.4. Historical instability in the food-energy-water nexus

This section will focus on specific aspects of the energy-food-water nexus which have contributed to the transformations outlined chronologically over the previous two centuries in Iran.

2.4.1. The ‘bread’ issue

The provision of wheat for bread has been a headache for all Iranian governments for at least the past century. Even before this, the provision of ‘wheat’ bread became a social and political issue in the nineteenth century when every aspect of its production and supply chain was almost primitive [7]. At some point in the nineteenth century, while sufficient wheat was produced for one city, people in another were starving due to hoarding or the lack of transportation [7]. A food shortage, notably of bread and rice, even forced a change in the Prime Ministership of Iran in 1917 [7]. In 1936, a governmental bureau was established to be responsible for supplying, maintaining, distributing and monitoring the quality of the strategic products of wheat, flour and bread as well as basic goods, including rice, oil, and sugar, etc. [43]. In relation to wheat sufficiency, the country has experienced being both a wheat-exporter and wheat-importer at different times throughout recent history. The country still imports wheat, rice, corn, and oilseeds due to domestic harvest failures as a result of droughts, pest plagues, plant diseases or floods. In 2021, Iran had to import 23,410,000 tonnes of agri-food products including wheat, barley, and oilseeds [35], while at the same time being a major exporter of fruit and vegetables [65]. Wheat production in 2022 rose by 45%, an increase attributed to government intervention through a higher guaranteed grain price and much lower fertilizer prices [64].

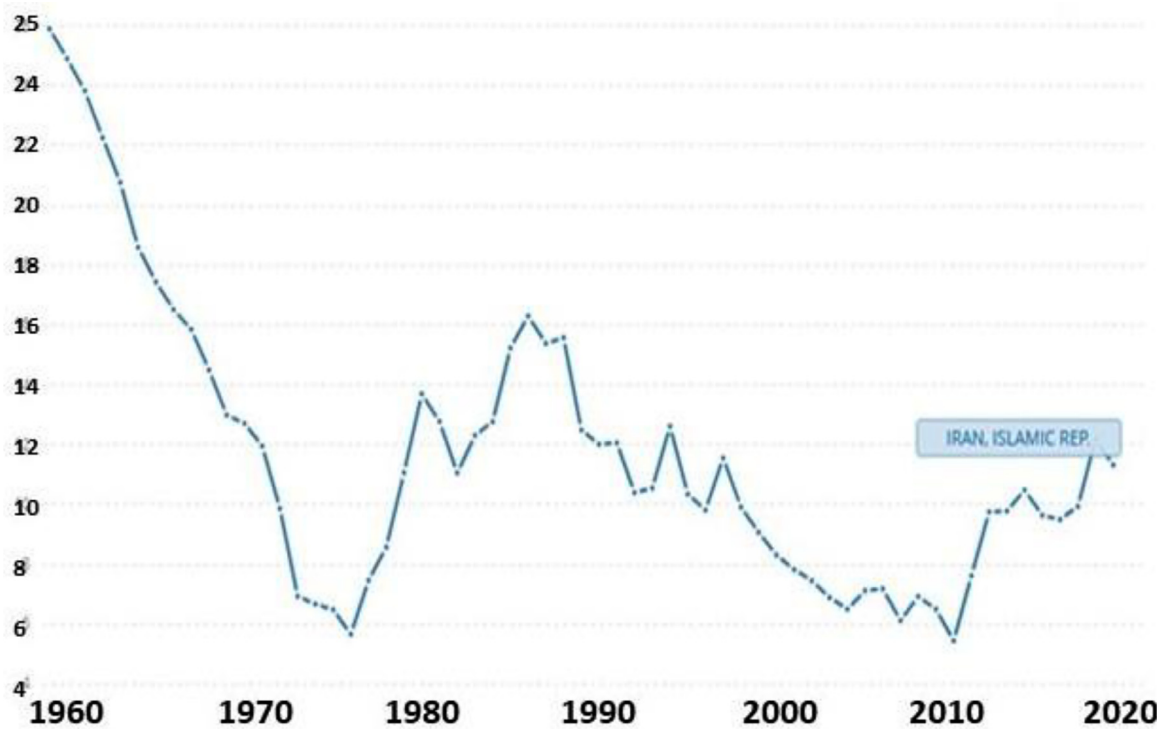


Fig. 2. The 60-year trend of the share of agriculture sector in national GDP (%). <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=IR>, accessed online 4/2/2022.

Table 4
Major challenges of agriculture sector in Iran.

Challenge	Subject	Remarks	Evidence/example
Water	Availability	Erratic rainfall	<ul style="list-style-type: none"> • Over 70% of rainfall occurs in 25% of the country’s area • 70% of water is lost by seepage from channels • 2% of agricultural land experiences efficient irrigation installations
	Consumption	Low water use efficiency; Agriculture is the biggest consumer of water in the country	<ul style="list-style-type: none"> • Agricultural water use efficiency as low as 35–40% • A total of 8.7 million ha of irrigated agricultural land exploits more than 90% of the total surface and groundwater resources and more than 60% of total renewable water resources
Mechanization	Tillage	Practicing traditional tillage over thousands of years without any change	<ul style="list-style-type: none"> • Using the high energy- consuming moldboard ploughs
	Sowing	Neglected precision sowing	<ul style="list-style-type: none"> • 75% of seed sown manually or by spreaders
Socio-economic	Fragmentation	Variability in size and fragmentation of farmlands	<ul style="list-style-type: none"> • 86.7% of arable land holders have less than 10 ha land
	Farmers	Insufficient farmer knowledge and income	<ul style="list-style-type: none"> • 45.4% illiterate (year 2005) with limited knowledge of markets and environment
Planning	Investment	Lack of systematic investment	<ul style="list-style-type: none"> • Only 0.06% of foreign investment was related to agriculture compared to 60% for industry (during the 17-year period 1993–2009)

Sources: [28,31,34,39,40,41,42].

2.4.2. Land degradation: A consequence of an unbalanced food-water equation

Throughout the history of Iran, agriculture has developed and intensified in response to a growing population and its demands for food and fibre. In the meantime, access to water, vegetation and land resources has been constrained as a result of loss of territory, wars, and the over-exploitation of resources. There is no doubt that agriculture played a pivotal role in this undeveloped nation until the early 1900s when almost 75% of the population was engaged in farming. However, un-

precedented population growth and subsequent socio-economic changes fueled by the discovery of oil changed this. Pressure has increased on the limited soil and water resources of this dryland country for the expansion of agriculture and development, with agriculture remaining the third largest provider of employment (18.6%, Latest Iran census, 2011: [44]).

In a dryland country such as Iran where frequent droughts, erratic and low rainfall are regarded as normal, inappropriate agricultural practices have derailed sustainable development, perhaps indefinitely, and

Table 5

Comparable data related to export/import of agricultural commodities (1981–2021) (US\$ billion).

Year	Import	Export	Import change - 1981 to 2021 (%)	Export change - 1981 to 2021 (%)
1981	3.11	0.18		
2021	7.81	4.52	251	2511

Sources: [26,35].

created the ‘point of no return’ condition seen in the form of desertification [45,46]. Each year, more and more farmers and land users are paying the price of this negligence by abandoning their lands; huge amounts of national income are lost in the name of subsidized agricultural inputs or purchase price guarantees provided by the Government; and parts of the country suffer extensive soil erosion and degradation of native vegetation and wildlife.

2.4.3. Agricultural exports and imports

There are few reliable documents to provide data on Iran’s trade before the 19th century, though an increase in cotton exports was reported during the 1790s [47]. Also, it is said that coffee was imported into Iran before the seventeenth century and became a popular daily drink for some Persians much earlier than tea [48]. From the 19th century, archives of foreign commissioners’ reports, travelogues and daily notebooks have shed light on Iran’s lifestyle and economy, including trade. Seyf [9] extracted data recorded on the export of opium during its heyday in nineteenth century Iran. An equivalent of 47,000 kg of opium was exported between 1862 and 1865, though this trade had gradually faded away by the early 20th century [9]. Other important exported crops included rice, cotton, tobacco, dried fruits and nuts [5]. In the nineteenth century, however, the country was importing tea, though many people could not afford it [48].

In the twentieth century, more reliable and official data on the export and import of Iran’s agricultural commodities were collected. Mojtahed and Esfahani [26] used FAO records from 1974 to highlight agricultural policies in Iran during the 1970s–1980s. Here, we use their 1981 data to compare changes in the most recent 40-year export/import of agricultural commodities in Iran. Table 5 shows that the country has actively exported and imported agricultural products, with a significant increase in the value of both exports and imports over this 40-year timeframe. These 2021 data must take account of the immense pressure the country was under for satisfying adequate food supplies due to population growth and droughts. At the regional level, values of food imports in the major oil-producing Middle East countries in 2017 were in the range of US\$1.26 to 15.67 billion [49], so Iran’s imports of US\$3.11 billion lie at the lower end of this range. Nevertheless, 2021 was an exceptional year affected by an unprecedented pandemic that interrupted many economic activities at the global level.

2.4.4. Food security in Iran: Historical perspective

Three points must be highlighted here:

First, no one can ignore that the availability of reliable statistics and data is a critical factor in identifying long-term phenomena such as food security. The developed countries began collecting national census data as early as the 18th century (e.g., 1749 in Sweden: [50]), before the Industrial Revolution. For Iran, this did not happen until the mid-20th century, when the first official censuses were initiated. Existing data and figures for Iran until then are speculative and unofficial.

Second, food insecurity is not an isolated issue related only to climatic factors or agricultural practices or crop diseases. Historians in developed countries have related social, economic and political disorders to food insecurity and malnutrition (e.g., Sweden: [50]). In this paper we have attempted to explore those ‘outliers’ while describing general food security challenges in Iran, such as connecting food security to oil exploration.

Third, famines and food shortages are not limited to non-developed societies. Famines in Ireland (e.g., [51]) and in Finland [52] during the 19th century are well-known examples. With the exception of the Great Famine and despite challenging circumstances, the available literature suggests that Iran has apparently experienced few significant famines and food shortages over the past two centuries.

3. Discussion

3.1. Future challenges

3.1.1. Climate change

Droughts and water shortages will undoubtedly prove to be major challenges for the future of Iranian agricultural activities and projects [53]. Lower rainfall and higher temperatures are predicted, especially in arid and semi-arid regions of the country. Gohari et al. [54] have forecasted the impacts of climate change on four major food crops (wheat, barley, rice, and corn) grown in the Zayandeh-Rud River Basin (one of the key semi-arid agricultural zones in Central Iran) for the period 2015–2044. According to their findings, monthly temperature will increase by 1.1 to 1.5 °C and precipitation will decrease by 11 to 31%. The reduction in yields of the four major food crops is estimated to be variously within a range of 1.4 to 20.7%. A shifting pattern in agro-ecological zones is foreseeable due to these climatic trends in the country.

3.1.2. Water usage productivity

Historically, water has been managed in dryland Iran using qanats, underground water channels connected to wells. However, illegal and excessive withdrawal of underground water, now aided by energy-consuming pumps, has become a problem. There are now an estimated 400,000 wells, a ten-fold increase since the 1970s [55]. Yet, despite a huge amount of capital works invested in constructing dams and auxiliary water channels, productivity of agricultural water is less than 35% [55] due to fragmented farms and low skill levels of the farmers. Unfortunately, 55% of irrigated wheat and 57% of rain-fed wheat are produced annually in water-scarce regions, seriously affecting future food self-sufficiency [40].

3.1.3. Destruction of farms

Increasing land prices in rural areas have enticed opportunists and land developers to encroach and destroy orchards and farmlands for building construction. This issue is especially challenging around the large cities such as Tehran. Despite punitive legislation banning such unlawful development activities, these encroachments still take place.

3.1.4. Reducing agricultural manpower

The agricultural sector in Iran has experienced a clear proportional reduction in manpower over the years: from around 90% of workers in the early twentieth century to 56% in 1956 (e.g., [55]), to 18.6% according to the latest Iran census, 2011 [44]. Currently, a changing attitude towards potential careers amongst the Iranian young generation is obvious. More high school graduates, whether in rural or urban areas, are inclining toward service-based, trade and industrial education and employment positions in cities. Even those graduating from agricultural disciplines are changing their careers for better paid positions in other sectors. In the long-term, this trend will have implications for the expansion of agriculture and the continuing aspiration for self-sufficiency

in agricultural products. To reverse this employment pattern, a national policy has been implemented to recruit new agricultural graduates who will contribute to a more skilled, technologically-based agricultural sector.

3.1.5. Insufficient crop storage capacity

Despite major investment in the construction of grain silos and storages made over the years, there is still a shortage of storage barns and silos. This is mostly due to the high prices of land and construction materials. The shortage of storage capacity has caused many crops and fruits to be kept in the open air and consequently become more vulnerable to infectious diseases and pests or be lost from exposure to rainfall.

3.1.6. Agrochemical pollution

Like other major agricultural producers, the country has suffered from the growing usage of pesticides and insecticides imported to the country mainly via uncertified international providers. The extensive monoculture has caused the emergence of weeds in cropping areas, necessitating the growing usage of herbicides (e.g., [56]). The first comprehensive research indicated that an annual average of 14,000 tonnes of agriculture pesticides (including herbicides, insecticides, and fungicides), expressed in active ingredients, were used in Iran in just two years (2012–2014) [57]. In addition to human health (e.g., [58]), the extensive usages of such agrochemicals endanger the health of water bodies. A study revealed that, for instance, elevated concentrations of diazinon were recorded in the three rivers of Haraz, Talar and Babolrood, located in the agricultural province of Mazandaran [59]. Following rejection of some exported fruit and vegetables by importing countries, Iran is introducing QR codes to identify production sources [66].

3.1.7. Geopolitical disruptors

Current geopolitical issues relating to the Russia-Ukraine war further complicate Iran's generally high rates of inflation which directly affect costs of agricultural inputs like fertilizer and machinery. This is reflected in higher prices for locally produced foodstuffs. Adding to inflationary pressures on consumers are rising costs of imported grain, whether directly for human consumption or indirectly for feeding livestock. Rates of inflation have historically fluctuated widely – from about 27% in 1978, 50% in 1995, and 12% in 2001 [60]. Since 2001, inflation rose to 35% in 2013, fell to 9% three years later, and then increased sharply to 40% by 2021 [61]. In the absence of energy subsidies, the recent rising cost of energy has led to higher food prices [63] and, at a national level, an agricultural sector characterised by suboptimal fertilizer usage [62] which may depress crop yields.

In addition to the emerging challenges outlined above, agriculture in Iran is also faced with the long-standing issues of soil degradation and salinity, land subsidence, and demographic shifts in favour of urban areas (e.g., [45,55]).

3.2. Policies for the future

We have portrayed agricultural production in Iran over a 200-year period. The hidden message of this article on the food-energy-water nexus is that effective food policies require planning for sustainable resources in a range of food-related areas, including land (soil quality, conservation), water (usage, storage, distribution technology), farm management (skilled workforce), and social/economic aspects (urban planning, crop storage/distribution, fluctuating production). These issues become more pronounced under the umbrella of predicted climate change. Many technical and ecological matters, and policies for improving Iran's agricultural sector, relate to maintaining a focus on sustainable resource use and are relevant and applicable to the broader Middle East region. Some of these critical issues for Iran and the region are outlined below:

- (a) It is recommended that the existing distribution of essential food crops be analysed and yields under the region's predicted climate

change be assessed. Due to the possible shifts in rainfall amounts and spatial patterns across the region, a plan for corresponding shifts in agricultural zones could be envisaged. This basic future-proofing information could be accompanied by devising strategies for supplementing water storage and infrastructure, and for crop storage;

- (b) The existing gap between farmers and governments could be filled through accelerating the extension and training services for farmers, and retaining and developing technical skills in the agricultural sector. This approach would be beneficial for increasing farming output and attracting a more highly skilled younger generation;
- (c) Of vital concern for maintaining sustainable agricultural production is the vigorous implementation of existing laws for protecting farmlands against excessive urban encroachment and the continued pursuit of efforts to control land degradation.

4. Conclusion

Agriculture in Iran is deeply-rooted in the country's history and it was a major income-generating sector up to the early twentieth century. However, there has been a gradual decline in agricultural employment for many reasons, but especially due to the rise of the oil industry which shifted the wider economy towards industry and services.

The period of 2011 onwards will be crucial to observe whether the recent investments in agriculture produce the expected benefits, as this period also coincides with the recent changes in subsidy regimes. Changes in subsidies will impact agricultural commodities and food in Iran in three ways. First, despite the Government continuing to support farmers financially, higher energy (electricity and fossil fuel) prices will affect the uptake of agricultural machinery and water pressure (irrigation) systems, potentially leading to a gradual abandonment of expensive and subsidized infrastructure and equipment. This may decelerate per capita agricultural productivity and optimization of water use. Second, higher energy prices mean that the cost of industrial chemical fertilizers and manures will increase, reminding us of those times during the nineteenth century when fertilizers were precious commodities in Iran. Third, an increase in unsubsidised energy prices may increase the price of petrochemical by-products used for food packaging and thus encourage food-processing companies to increase the price of their products. Gradually, local products may lose their competitiveness, both in terms of quality and quantity, leading to increasing importation of agricultural and food products.

These trends imply that agriculture will not be an attractive career path for young people. In addition, the persistent shortage of water resources and continuing soil loss will increasingly become impediments for future agricultural development in the country. Considering these factors in an environment of predicted population increase makes the materialization of any agricultural self-sufficiency plan difficult, if not impossible. However, there are hopes that high capital investment in expansion of pressurized irrigation and water management structures, development of modified crop varieties, provision of low-interest loans for local glasshouse production and the employment of modern machinery and highly skilled manpower will provide better circumstances for adaptation to climate change in the long-term.

Over the past two centuries, despite climatic uncertainties (droughts), social perturbations (population growth and revolutions), and political upheavals (regional war and international sanctions), Iran has generally managed to escape frequent famines and acute food shortages. The country has exported agricultural commodities while being dependent on importing certain products (notably wheat) from time to time, reflecting the pattern of rainy seasons (exports) and drought periods (imports). The share of agriculture in national GDP has fluctuated widely around a declining trend since 1960 but has never regained its previous importance. Although a slight upward trend in agricultural GDP is evident after 2010, this trend is highly unlikely to approach or surpass the services and industry sectors in the future.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgment

Parts of this manuscript were written during the Cheney Fellowship awarded to FA by the University of Leeds (2015–16). FA also appreciates Emeritus Prof. Les Fairbank who commented on the earlier draft of this manuscript.

References

- [1] B. Spooner, City and river in Iran: urbanization and irrigation of the Iranian plateau, *Iranian Stud.* 7 (3–4) (1974) 681–713, doi:10.1080/00210867408701484.
- [2] K. Abdi, The early development of pastoralism in the Central Zagros Mountains, *J. World Prehist.* 17 (4) (2003) 395–448, doi:10.1023/B:JOWO.0000020195.39133.4c.
- [3] C.C. Lamberg-Karlovsky, The earliest communities of Iran, *Iranian Stud.* 2 (1) (1969) 2–7, doi:10.1080/00210866908701370.
- [4] IMF, 2011. Iran: the chronicles of the subsidy reform. Vol. 2011: Issue 167, <https://www.elibrary.imf.org/view/journals/001/2011/167/article-A001-en.xml>, accessed online 19/2/2022.
- [5] N.R. Keddie, The economic history of Iran, 1800–1914, and its political impact an overview, *Iranian Stud.* 5 (2–3) (1972) 58–78.
- [6] C. Issawi, Iranian trade, 1800–1914, *Iranian Stud.* 16 (3) (1983) 229–241.
- [7] W.M. Floor, The creation of the food administration in Iran, *Iranian Stud.* 16 (3–4) (1983) 199–227, doi:10.1080/00210868308701614.
- [8] R.A. McDaniel, Economic change and economic resiliency in 19th century Persia, *Iranian Stud.* 4 (1) (1971) 36–49, doi:10.1080/00210867108701407.
- [9] A. Seyf, Commercialization of agriculture: production and trade of opium in Persia, 1850–1906, *Int. J. Middle East Stud.* 16 (2) (1984) 233–250, doi:10.1017/S0020743800027951.
- [10] S. Okazaki, The great Persian famine of 1870–71, *Bull. Sch. Orient. Afr. Stud.* 49 (1) (1986) 183–192 University of London, Honour of Ann K. S. Lambton (1986), doi:10.1017/S0041977X00042609.
- [11] A. Seyf, Iran and the great famine, 1870–72, *Middle East. Stud.* 46 (2) (2010) 289–306, doi:10.1080/00263201003616584.
- [12] A. Seyf, Nineteenth-century agricultural development in Iran: a note, *Middle East. Stud.* 28 (3) (1992) 577–587.
- [13] H.S. Esfahani, M.H. Pesaran, The Iranian economy in the twentieth century: a global perspective, *Iranian Stud.* 42 (2) (2009) 177–211.
- [14] A.E. Kojoori-Saatchi, The culture of revolution: Revolutionary transformation in Iran, UNLV Theses, Dissertations, Professional Papers, and Capstones, 2010, doi:10.34917/2153789.
- [15] F. Amiraslani, D. Dragovich, Combating desertification in Iran over the last 50 years: an overview of changing approaches, *J. Environ. Manage.* 92 (2011) 1–13.
- [16] J. Bharier, The growth of towns and villages in Iran, 1900–66, *Middle East. Stud.* 8 (1) (1972) 51–61.
- [17] W. Floor, Industrialization in Iran 1900–1941, in: Occasional Papers Series No. 23, University of Durham, Centre for Middle Eastern and Islamic Studies, UK, 1984, p. 69.
- [18] F.A. Hessari, Sectoral energy consumption in Iran, *Renew. Sustain. Energy Rev.* 9 (2) (2005) 203–214.
- [19] A. Tavakoli, Nationalization and efficient management of water resources in Iran, *J. Water Resour. Plann. Manage.* 113 (4) (1987) 522–532.
- [20] A. Seyf, On the importance of irrigation in Iranian agriculture, *Middle East. Stud.* 42 (4) (2006) 659–673.
- [21] M.A. Katouzian, Oil versus agriculture: a case of dual resource depletion in Iran, *J. Peasant Stud.* 5 (3) (1978) 347–369.
- [22] M. Yazdanpanah, D. Hayati, G. Zamani, F. Karbalaee, S. Hochrainer-Stigler, Water management from tradition to second modernity: an analysis of the water crisis in Iran, *Environ. Dev. Sustain.* 15 (2013) 1605–1621.
- [23] E. Hooglund, Iran's agricultural inheritance, *Merip Rep.* 99 (1981) 15–19.
- [24] A.K.S. Lambton, The Persian Land Reform, Oxford University Press, 1970.
- [25] M.G. Weinbaum, Agricultural policy and development politics in Iran, *Middle East J.* 31 (4) (1977) 434–450.
- [26] F.A. Mojtahed, H. Esfahani, Agricultural Policy and performance in Iran: the post-revolutionary experience, *World Dev.* 17 (6) (1989) 839–860.
- [27] ISNA. Islamic Student News Agency. www.isna.ir. Frequent visits on dates mentioned within the text (In Persian).
- [28] E. Karamidehkordi, A country report: challenges facing Iranian agriculture and natural resources management in the twenty-first century, *Hum. Ecol.* 38 (2010) 295–303.
- [29] UN, in: United Nations technical Mission On the Drought Situation in the Islamic Republic of Iran, WEF, 2000, p. 35. (2013). Lessons drawn from reforms of energy subsidies. World Economic Forum.
- [30] World Bank, Natural disasters in the Middle East and North Africa: a regional overview, in: The International Bank for Reconstruction and Development, The World Bank, 2014, p. 114.
- [31] IRNA. Islamic Republic News Agency. www.irna.ir. Frequent visits on dates mentioned within the text (In Persian).
- [32] S.S. Hosseini, E. Hassanpour, S.Y. Sadeghian, An economic evaluation of Iranian public agricultural R&D policy: the case of sugarbeet, *Res. Policy* 38 (9) (2009) 1446–1452.
- [33] ICCIMA, Iran chamber of commerce, industries, mines and agriculture/The Analytical Report of Self-Sufficiency of Food and Agriculture in Iran, 2011 <https://iccima.ir/fa/> accessed 24 June 2011 (In Persian).
- [34] OIETAI (2011). Organization for Investment Economic and Technical Assistance of Iran. https://www.investiniran.ir/oieta_content/en/investmengineid/approvedproject/Forinvestmenstatistic-n.pdf, accessed 3 January 2011.
- [35] MoA, 2022. Ministry of Agriculture website-Iran, <https://maj.ir/index.aspx?lang=1^{sub}=0>, accessed frequently in Jan-Feb 2022.
- [36] A. Karami, A. Esmaeili, B. Najafi, Assessing effects of alternative food subsidy reform in Iran, *J. Policy Model.* 34 (2012) 788–799.
- [37] J. Amid, The dilemma of cheap food and self-sufficiency: the case of wheat in Iran, *Food Policy* 32 (2007) 537–552.
- [38] UNDP (2012). Energy subsidies in the Arab World. <http://www.undp.org/content/dam/undp/library/Environment%20and%20Energy/UNDP-EE-AHDR-Energy-Subsidies-2012-Final.pdf>, accessed online 19/2/2022.
- [39] I. Beheshti Tabar, A. Keyhani, S. Rafiee, Energy balance in Iran's agronomy (1990–2006), *Renew. Sustain. Energy Rev.* 14 (2) (2010) 849–855.
- [40] M. Faramarzi, K.C. Abbaspour, R. Schulin, H. Yang, Modelling blue and green water resources availability in Iran, *Hydrol. Process.* 23 (3) (2009) 486–501.
- [41] M.H. Karimkoshteh, M. Haghiri, Water-reform strategies in Iran's agricultural sector, *Perspect. Global Dev. Technol.* 3 (3) (2004) 327–346.
- [42] NAPNational Action Programme to Combat Desertification and Mitigate the Effects of Drought of Islamic Republic of Iran, Forest, Rangeland and Watershed Management Organization, Ministry of Jihad Agriculture, Tehran, 2005.
- [43] GTC, 2021. <http://gtcl.org/fa/content>, accessed online 25/5/2021/.
- [44] SCI, 2011. Statistical Center for Iran. <https://www.amar.org.ir/english/Labor-Force>, accessed online 9/2/2022.
- [45] F. Amiraslani, D. Dragovich, Combating desertification in Iran over the last 50 years: an overview of changing approaches, *J. Environ. Manage.* 92 (2011) 1–13.
- [46] F. Amiraslani, D. Dragovich, Cross-sectoral and participatory approaches to combating desertification: the Iranian experience, *Nat. Resour. Forum* 34 (2) (2010) 140–154.
- [47] T.M. Ricks, Towards a social and economic history of eighteenth-century Iran, *Iranian Stud.* 6 (2) (1973) 110–126.
- [48] R. Matthee, From coffee to tea: shifting patterns of consumption in Qajar Iran, *J. World Hist.* 7 (2) (1996) 199–230.
- [49] C. Henderson, The rise of Arab Gulf agro-capital: continuity and change in the corporate food regime, *J. Peasant Stud.* (2021), doi:10.1080/03066150.2021.1888723.
- [50] F.L.G. Utterström, Some population problems in pre-industrial Sweden, *Scand. Econ. Hist. Rev.* 2 (2) (1954) 103–165, doi:10.1080/03585522.1954.10407619.
- [51] E.M. Crawford, Dearth, diet, and disease in Ireland, 1850: a case study of nutritional deficiency, *Med. Hist.* 28 (1984) 151–161.
- [52] M. Dribe, M. Olsson, P. Svensson, Famines in the Nordic countries, AD 536-1875, Department of Economic History, Lund University, 2015 Lund papers in Economic History. General Issues, No 138.
- [53] F. Amiraslani, A. Caiserman, Contemporary water resource management and its role in tackling land degradation and desertification in Iran, in: Standing Up to Climate Change: Creating Prospects For a Future in Rural Iran, Springer Publication, 2020, pp. 65–87.
- [54] A. Gohari, S. Eslamian, J. Abedi-Koupaei, A. Massah Bavani, D. Wang, M. Madani, Climate change impacts on crop production in Iran's Zayandeh-Rud River Basin, *Sci. Total Environ.* 442 (2013) 405–419.
- [55] I. Emadodin, D. Narita, H. Rudolf Bork, Soil degradation and agricultural sustainability: an overview from Iran, *Environ. Dev. Sustain.* 14 (2012) 611–625.
- [56] I. Nosrattia, P. Sabeti, G. Chaghmirzaee, H. Heidari, Weed problems, challenges, and opportunities in Iran, *Crop Prot.* 134 (2020) 104371, doi:10.1016/j.cropro.2017.10.007.
- [57] M. Zaim, S.B. Mousavi, M.A. Baghestani, A. Aitio, An assessment of agricultural pesticide use in Iran, 2012-2014, *J. Environ. Health Sci. Eng.* 15 (2017) 10, doi:10.1186/s40201-017-0272-4.
- [58] M. Sookhtanlou, M.S. Allahyari, J. Surujjal, Health risk of potato farmers exposed to overuse of chemical pesticides in Iran, *Saf. Health Work* 13 (2022) 23–31.
- [59] R. Dahmardeh Behrooz, A. Esmaili-sari, M. Urbaniak, P. Chakraborty, Assessing Diazinon pollution in the three major rivers flowing into the Caspian Sea (Iran), *Water (Basel)* 13 (2021) 335, doi:10.3390/w13030335.
- [60] World Bank, 2023. Inflation, consumer prices (annual%) – Iran, Islamic Rep. <https://data.worldbank.org/indicator/FP.CPL.TOTL.ZG?locations=IR> Accessed 25 January 2023.
- [61] Statista, 2023. Iran – inflation rate from 1987 to 2021. <https://www.statista.com/statistics/294320/iran-inflation-rate/>. Accessed 25 January 2023.
- [62] Financial Tribune, 2022. Fertilizer consumption in Iran falls short of global average. <https://financialtribune.com/articles/domestic-economy/116378/fertilizer-consumption-in-iran-falls-short-of-global-average>. Accessed 25 January 2023.

- [63] R. Radmehr, S.R. Henneberry, Energy price policies and food prices: empirical evidence from Iran, *Energies* 13 (2020) 4031, doi:10.3390/en13154031.
- [64] Financial Tribune, 2023. Wheat production rises 45% to 11.5 m tons in last crop year. <https://financialtribune.com/articles/domestic-economy/116464/wheat-production-rises-45-to-115m-tons-in-last-crop-year>. Accessed 1 February 2023.
- [65] Tehran TimesIran Among World's Top Agro-Food Exporters in 2021, FAO, 2023 <https://www.tehrantimes.com/news/480539/Iran-among-world-s-top-agro-food-exporters-in-2021> Accessed 1 February 2023.
- [66] Tehran Times, 2023. All agricultural products to be exported with QR code from late March. <https://www.tehrantimes.com/news/480492/All-agricultural-products-to-be-exported-with-QR-code-from-late>. Accessed 1 February 2023.