IOM UN MIGRATION | GLOBAL DATA INSTITUTE DISPLACEMENT TRACKING MATRIX

# DRIVERS OF CLIMATE-INDUCED DISPLACEMENT IN IRAQ

## CLIMATE VULNERABILITY ASSESSMENT

OCTOBER 2023

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# ACRONYMS

| | |
|---|---|
| **CHAID** | Chi-Square Automatic Interaction Detection |
| **DTM** | Displacement Tracking Matrix |
| **ET** | Emergency Tracking |
| **HHs** | Households |
| **IOM** | International Organization for Migration |
| **NASA** | National Aeronautics and Space Administration |
| **NDVI** | Normalized Difference Vegetation Index |
| **NIR** | No Information Rate |
| **RARTs** | Rapid Assessment and Response Teams |
| **WFP** | World Food Programme |

# EXECUTIVE SUMMARY

Climate change[1] and environmental degradation[2] have contributed to the displacement of at least 55,290 individuals in assessed locations in central and southern Iraq between January 2016 and October 2022.[3, 4] This figure represents an estimated 15 per cent of the original population[5] that used to reside in these locations. In other words, **more than 1 in 10 people from these locations have been displaced in the past six years**. Given the uptick in environmental migration observed in 2022, this trend is expected to worsen, particularly in the absence of adequate mitigation and adaptation strategies.[6, 7]

To better understand the root causes of these movements, the International Organization for Migration's (IOM) Displacement Tracking Matrix (DTM) developed a tool to assess a location's vulnerability to climate-induced displacement. The tool measured four dimensions: 1) environmental hazards and water access, 2) services and infrastructure, 3) livelihoods and mitigation measures[8] and 4) tension and conflict. This section presents the key findings across these dimensions. This assessment examined conditions in locations that have already recorded climate-induced displacement,[9] as measured by IOM DTM's Climate Emergency Tracking tool.[10] Data collection for this assessment took place between August and October 2022 across nine governorates, 29 districts and 262 locations. IOM's Rapid Assessment and Response Teams (RARTs) collected these data through interviews with key informants (KIs) at the location level. These interviews were triangulated using the normalized difference vegetation index (NDVI) anomaly data, which measure changes in the 'greenness' of vegetation cover and are used as a proxy to compare the density and health of vegetation over time. The NDVI anomaly data were extracted from the United States Geological Survey/National Aeronautics and Space Administration (NASA) Landsat remote sensing data[11] and analysed in partnership with the World Food Programme's Vulnerability and Analysis Mapping team.

## PRE-EXISTING VULNERABILITIES

Environmental degradation and climate change impact different groups in different ways and to differing degrees. The families who likely face the greatest challenges are those who rely on land and water resources for income, struggle to access basic services and experience tensions over natural resources.[12] Ineffective water management policies, broken or inefficient water infrastructure and damming or diversions by upstream governorates and countries also contribute to unequal access to available water resources.[13, 14, 15] Together, these factors shape the ability of people to withstand the environmental hazards confronting them in central and southern Iraq, such as drought, sand/dust storms, increased water salinity and reduced water levels.

## IMPACTS OF CLIMATE CHANGE AND ENVIRONMENTAL DEGRADATION

Adverse environmental conditions can lead to lower crop and fishing yields and a reduced capacity to feed livestock. In response, some families have abandoned agricultural, livestock and fishing livelihoods altogether.[16] Additionally, land degradation and increasingly scarce water resources can contribute to tension in communities. These tensions, in turn, make cooperative approaches towards water management more challenging.[17,18,19] Moreover, climate change and environmental degradation make locations less habitable by impeding the ability of households to meet their most essential needs. For example, water shortages impact individual health outcomes while also increasing community-level health risks such as infectious disease outbreaks. In the face of these stressors, some families send members of the household to different locations in search of a job, while others reduce their expenses or sell assets, land or livestock. If conditions persist, families may displace to other locations.

Accordingly, in contexts where climate change and environmental degradation are worsening living conditions and making traditional livelihoods less sustainable, displacement from these areas serves as a strategy to cope with deteriorating environmental conditions. Given the resources required to move, however, **people who are displaced by environmental factors are not necessarily those most impacted or those with the greatest needs or vulnerability.** Families who remain behind may lack the means to relocate, forming a potential 'trapped population.'[20, 21, 22]

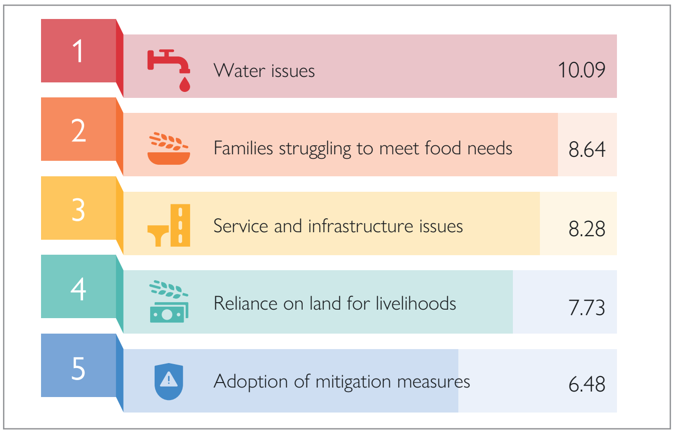
1 The United Nations Framework Convention on Climate Change defines climate change as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to other natural climate variability that has been observed over comparable time periods.' IOM, *Migration, Environment and Climate Change: Evidence for Policy Glossary* (Geneva, 2014).
2 The United Nations Office for Disaster Risk Reduction (UNDRR) defines environmental degradation as '[t]he reduction of the capacity of the environment to meet social and ecological objectives and needs. […] Degradation of the environment can alter the frequency and intensity of natural hazards and increase the vulnerability of communities. The types of human-induced degradation are varied and include land misuse, soil erosion and loss, desertification, wildland fires, loss of biodiversity, deforestation, mangrove destruction, land, water and air pollution, climate change, sea level rise and ozone depletion.' IOM, *Migration, Environment and Climate Change: Evidence for Policy Glossary* (Geneva, 2014).
3 International Organization for Migration, *Displacement Tracking Matrix – Climate-Induced Displacement – Central and Southern Iraq* (Baghdad, September 2022).
4 As of June 2023, DTM has recorded the displacement of 83,520 individuals in central and southern Iraq. International Organization for Migration, *Displacement Tracking Matrix – Climate-Induced Displacement – Central and Southern Iraq* (Baghdad, July 2023).
5 The original population refers to people who have displaced from assessed locations as well as the population who continue to reside there.
6 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
7 Lisa Binder, Barbora Šedová, Lukas Rüttinger, Julia Tomalka & Stephanie Gleixner, *Climate Risk Profile: Iraq*, Potsdam Institute for Climate Impact Research & adelphi (Potsdam, 2022).
8 Mitigation measure is used here to refer to: 'an action taken by individuals within a household when shocks, such as natural disasters and conflict, push them beyond the difficulties faced in 'normal' times.' The term 'mitigation measure' is used instead of 'coping strategy' as the latter term is commonly used as a measure of food security. Oxfam, *Measuring Household Stress: Introducing the multi-sector Coping Strategy Index for Afghanistan* (Baghdad, May 2018).
9 DTM used its Climate Emergency Tracking tool to determine which locations have already recorded climate-induced displacement.
10 All of IOM DTM's Climate Emergency Tracking reports can be found here.
11 Landsat Missions, Landsat Normalized Difference Vegetation Index, *United States Geological Survey* (n.d., Reston).
12 Roger Guiu, *When Canals Run Dry: Displacement Triggered by Water Stress in the South of Iraq*, Internal Displacement Monitoring Centre, Social Inquiry & Norwegian Refugee Council (Geneva, 2020).
13 Action Contre la Faim & REACH, *Climate Motivated Displacement: Baseline* (Erbil, 2022).
14 Roger Guiu, *When Canals Run Dry: Displacement Triggered by Water Stress in the South of Iraq*, Internal Displacement Monitoring Centre, Social Inquiry & Norwegian Refugee Council (Geneva, 2020).
15 World Food Programme and Social Inquiry, *Prospects for Resilience Amid Fragility: Conflict Analysis of Al-Qurna and Al-Dair Districts in Basra Governorate* (Baghdad, 2022).
16 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
17 Ibid.
18 World Food Programme & Social Inquiry, *Prospects for Resilience Amid Fragility: Conflict Analysis of Al-Qurna and Al-Dair Districts in Basra Governorate* (Baghdad, 2022).
19 World Food Programme & Social Inquiry, *Improving Prospects for Peace and Stability in Vulnerable Communities in Southern Iraq. Thi-Qar Governorate Conflict Analysis* (Baghdad, 2022).
20 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
21 IOM, Intersessional workshop on climate change, environmental degradation and migration: Background paper, *International Dialogue on Migration* (Geneva, 2011).
22 IOM defines trapped populations as '[p]opulations who do not migrate, yet are situated in areas under threat, […] at risk of becoming 'trapped' or having to stay behind, where they will be more vulnerable to environmental shocks and impoverishment.' IOM notes that trapped population may be 'poorer households who may not have the resources to move and whose livelihoods are affected.' IOM, *Migration, Environment and Climate Change: Evidence for Policy Glossary* (Geneva, 2014).

## OVERALL VULNERABILITY

The analysis for this section comes from a Random Forest classification algorithm. For a description of the model and methodology, please see the Methodology and Annex of this report.

- The strongest predictor of the rate of depopulation (that is, the portion of the original population displaced due to environmental factors) is the **presence of multiple water-related issues**, such as reduced rainfall, lower water allocation and broken or inefficient water infrastructure.[23] As certain water-related problems are widespread, not all issues are associated with high rates of depopulation. In particular, a reduction in irrigation sources, a decrease in rainfall and a decline in water quality are common to nearly all locations, regardless of depopulation rate. On the other hand, the **cost of water trucking and damming or river diversions** are specific water issues associated with higher rates of depopulation.
- **Families struggling to meet their basic food needs** is the second strongest predictor of the depopulation rate. This suggests that those being displaced are in a particularly vulnerable economic position.
- The third strongest predictor of the depopulation rate is **difficult access to services or infrastructure**. This highlights the vulnerability of families residing in remote rural locations, where access to education, health care and markets may be more challenging.
- **Reliance on land for livelihoods** is the fourth strongest predictor of displacement. Changes in the environment have a greater impact on farmers, livestock herders, fishers and transhumant pastoralists,[24] as they depend on favourable environmental conditions to make a living.
- The fifth strongest predictor of displacement is the **adoption of mitigation measures** by families. Reliance on mitigation measures indicates that families have been negatively impacted by changes in the environment and are taking steps to overcome these challenges. The most common mitigation measure, that is, sending households members to another location to make money, points to the lack of alternative livelihood opportunities in the area. However, this measure also enables families to raise money to remain or relocate. Other tactics, such as borrowing money, reducing meal size or taking children out of school, undermine the well-being and resilience of families. If the situation persists, families may be forced to leave the area.

Figure 1. Top five predictors of climate-induced depopulation



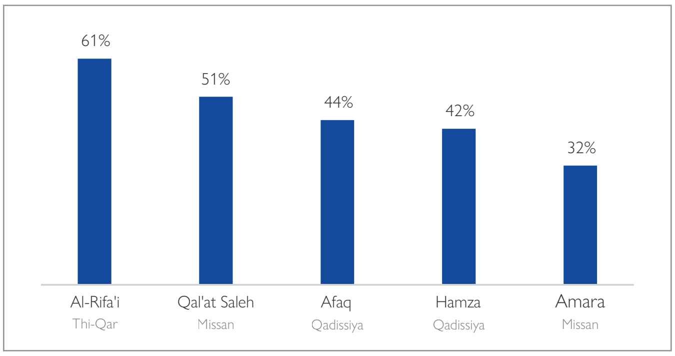

Note: Based on mean decrease in Gini coefficient from Random Forest analysis.

## DISPLACEMENT DYNAMICS

Nearly 62,000 families live in locations where climate-induced displacement is taking place. In around two thirds of locations, over one in five people had already left due to environmental issues at the time of the assessment (Map 1).

- The districts recording the highest levels of climate-induced displacement are:
  - **Qal'at Saleh (Missan Governorate),** where **half of the population** in assessed locations has been displaced (1,728 families);
  - **Al-Rifa'i (Thi-Qar Governorate),** where **three in five households** in assessed locations have been displaced (1,321 families);
  - **Nassriya (Thi-Qar Governorate)**, where **nearly one in five households** in assessed locations have been displaced (1,257 families).
- **Ten locations have been fully abandoned**. Most of these locations are in Thi-Qar Governorate, including five locations in Nassriya and three in Suq Al-Shoyokh.
- As of December 2022, 4,360 more families (26,160 individuals) were displaced by climate change and environmental degradation in 2022 compared to 2021, representing an eight-fold increase (+803%).
- This increase is partially attributable to growing trends of climate-induced displacement in Diyala, Babylon, Thi-Qar and Wassit governorates. More than three quarters of climate-induced displacement in these governorates took place in 2022. The primary drivers of displacement in these governorates in 2022 appear to be low rainfall and low water levels in the rivers and tributaries. Additional aggravating factors include low levels of groundwater, water salinization, disputes over water allocation and restrictions by the Government on the use of water.

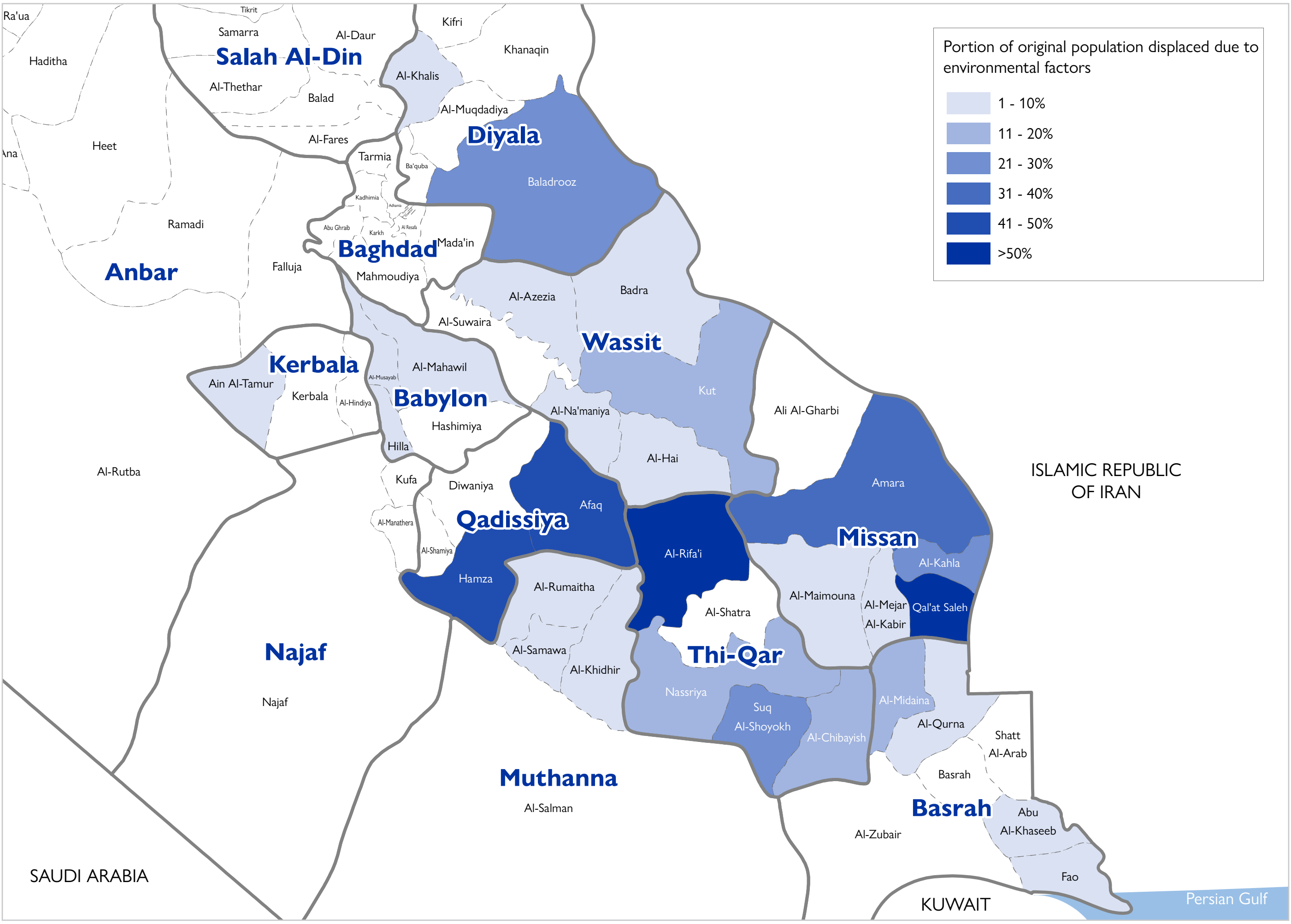
Figure 2. Districts with highest portion of population displaced




23 Water-related issues include: 1) a reduction in irrigation water supply, 2) damming or river diversions, 3) reduced rainfall patterns, 4) broken or inefficient water infrastructure, 5) reduced water allocation, 6) reduced water quality (e.g. salinity or pollution), 7) population growth/intensive agriculture and 8) rising costs of water trucking.

24 Transhumance is defined as the 'seasonal movement of people with their livestock between pastures (typically between mountain and lowland pastures) often over long distances, and sometimes between borders. The term is often used as a synonymous [sic] of pastoralism.' IOM, *International Migration Law No. 34, Glossary on Migration* (Geneva, 2019).

Map 1. Portion of original population displaced due to environmental factors




## ENVIRONMENTAL HAZARDS AND WATER ACCESS

- Many locations are confronting multiple extreme weather and slow-onset events. Nearly three quarters of locations experienced 6–8 types of hazards. The most common hazards, reported in over 85 per cent of locations, are **droughts** and **sand/dust storms**. Additionally, most locations reported **increased water salinity, soil degradation** and **changing rainfall patterns**.
- Almost all locations reported a **decrease in irrigation water supply** in the past 12 months. KIs primarily attributed this reduction to **reduced rainfall patterns**, as well as **reduced water quality**, making water sources unsuitable for irrigation. Additionally, at least half of locations pointed to the impact of **water allocation** and **damming/river diversions**, connected to a lack of international water sharing agreements and inequitable distribution within the country.[25] Furthermore, just over one third of locations cited ineffective water management, in the form of broken or inefficient water infrastructure, as a cause of this dwindling supply.

## SERVICES AND INFRASTRUCTURE

- **Access to basic services[26] is a challenge in most locations**. The service most difficult to access was **water**. In just under two thirds of locations, less than 75 per cent of households had enough water for drinking or domestic purposes.
- Across governorates, **Thi-Qar** reported the worst access to services, with nearly half of locations lacking access to all or nearly all services assessed. At the district level, **Al-Rifa'i** in Thi-Qar, **Baladrooz** in Diyala, **Amara** in Missan and **Al-Samawa** and **Al-Rumaitha** in Muthanna reported the highest portions of locations lacking access to all or nearly all services.
- **Support to these communities remains limited**, despite the widespread challenges they face. Only 5 per cent of locations reported receiving aid or assistance[27] from the Government of Iraq, humanitarian organizations, local charities, relatives and friends or other sources.

25 Nussaibah Younis, Early warning: How Iraq can adapt to climate change, *European Council on Foreign Relations* (Berlin, 2022).
26 Services assessed include electricity, water for drinking and domestic use, reliance on water trucking, primary and secondary education, health care, markets and access to aid or assistance.
27 If KIs responded affirmatively that households in the locations had received any aid or assistance, they were asked the source of this aid (e.g. government assistance, humanitarian organizations, charity from the local community, relatives and friends or other). They were then asked what form of assistance had been received. Options included: housing reconstruction, temporary shelter, agricultural input subsidies, subsidized water supply, cash assistance/social safety net, in-kind food aid, psychosocial care, water, sanitation and hygiene assistance, education assistance, agricultural assistance or other.

## LIVELIHOODS

- Agriculture and livestock rearing are among the top livelihood activities in most locations assessed. Nearly all locations indicated **loss of crop production, livestock deaths or reduced fishing yields** as a result of environmental factors. A similar portion **struggled to feed livestock**. As a result, **large-scale abandonment of agricultural, livestock and fishing activities** is taking place. In 71 per cent of locations, over half of households no longer practice these trades.
- Changes to the environment are also causing households to adopt mitigation measures, as cited by KIs in 75 per cent of locations. Among locations where families are adopting mitigation measures, nearly all reported sending household members to another location to make money. Other common mitigation measure include conserving water and reducing household expenditure.

## TENSION AND CONFLICT

- Tension and conflict related to natural resources appear to be a localized issue, reported by only seven districts including Nassriya, Kut and Suq Al-Shoyokh districts.
- Disputes over natural resources led to the displacement of households in three districts, namely Al-Qurna, Nassriya and Kut districts.
- In locations reporting tension or conflict over natural resources, key informants in more than four in five locations said such tensions have increased in the past year.
- Tensions or conflict over natural resources primarily revolves around water, grazing land, livestock and arable land. Triggers for tension or conflict often involved disagreements over water sharing, especially the perception that farmers were exceeding their water quota.[28] Disputes tend to arise between members of the same tribe or ethno-religious group sharing the same livelihoods.

## RECOMMENDATIONS

- Water-related issues are the top driver of climate-induced displacement in Iraq. Addressing these challenges will require **greater cooperation on the distribution of water resources between Iraq and neighbouring countries,** the development of **more equitable water management policies** within Iraq, **improvement of existing water infrastructure** and **acquisition of climate-smart infrastructure** and **awareness-raising campaigns** around water conservation.[29]
- Additionally, communities in central and southern Iraq require greater support to **diversify livelihood options** and **expand the provision of basic services**, especially access to water for drinking and domestic use.
- As tensions and conflict over natural resources tend to revolve around water, support should be provided to communities to develop **monitoring systems related to water scarcity** and **platforms for dialogue and mediation.** Further research and analysis should be conducted to understand the relationship between environmental stress and tensions or conflict in Iraq, particularly in areas of displacement for climate migrants.
- Many locations are experiencing wide-ranging challenges across the domains considered. However, based on a composite measure of all issues assessed, 10 districts have shown particularly high levels of vulnerability including:
  - **Qadissiya Governorate:** Afaq and Hamza districts;
  - **Missan Governorate:** Al-Maimouna, Al-Mejar Al-Kabir, Amara, Qal'at Saleh and Al-Kahla;
  - **Thi-Qar Governorate:** Al-Rifa'i, Nassriya and Suq Al-Shoyokh districts.
- Policies related to disaster risk reduction, climate change and development should take into account the vulnerability and needs of those who have displaced and may displace in the future.[30, 31]
- Further data collection and research aimed at assessing and monitoring the impact of climate change and environmental degradation on living conditions are needed. While this assessment collected data at the location level, more granular assessments disaggregated by sex and age could shed light on the different consequences faced by different identity groups. Moreover, monitoring activities should integrate the perspectives of impacted families with remote sensing and satellite data on key environmental indicators.[32] Given the potential for greater climate-induced displacement in the future, researchers and programmatic actors should further develop early warning or predictive models which could signal shifting trends in the short- to long-term, building on existing examples.[33, 34] Local authorities and the central government should be provided with technical assistance on data collection and analysis to build their capacity to assess, monitor and address the consequences of climate change and environmental degradation based on their data.

28 This information was collected as part of a follow-up for qualitative information with the Rapid Assessment Response Teams.
29 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
30 Ibid.
31 IOM, *People on the Move in a Changing Climate – Linking Policy, Evidence and Action* (Geneva, 2022).
32 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
33 Ibid.
34 IOM, *Somalia – Drought Related Displacement Analysis (December 2021)* (Mogadishu, 2022).

# INTRODUCTION

Migration in response to environmental degradation and natural hazards[35] is a growing trend.[36] As climate change raises the intensity and frequency of environmental hazards such as droughts, floods and storms, more and more people are expected to leave their homes.[37] Additionally, unpredictable temperatures and rainfall patterns affect people practising land- and water-based livelihoods, with important consequences for food security and living conditions.[38]

Iraq is already witnessing the effects of climate change and environmental degradation.[39] Temperatures are rising,[40] rainfall is decreasing,[41] droughts are more severe,[42] water scarcity is increasing,[43] sand and dust storms and flooding are more frequent.[44, 45] Strikingly, temperatures in Iraq are soaring up to seven times faster than the global average, while annual rainfall is predicted to decrease by 9 per cent by 2050.[46] Adding to these challenges, damming and other water management policies in neighbouring countries have reduced Iraq's water supply.[47] At the same time, Iraq's demand for water continues to rise due to a growing population, the expansion of cities and inefficient agricultural and industrial practices.[48]

As the processes of climate change and environmental degradation intensify, the number of environmental migrants is likely to increase significantly.[49] The drivers of environmental migration – and their impact on vulnerable communities – are a critical area of research needed to inform targeted programming and advocacy.

The International Organization for Migration's (IOM) Displacement Tracking Matrix (DTM) in Iraq has conducted emergency tracking (ET) of families displaced by drought conditions since June 2018.[50] Enumerators continually collect data on locations of displacement, the number of families displaced, the type of shelter in which they reside and the year of their displacement.[51] These figures are then published in quarterly reports.[52] However, not enough is known about what drove these families to displace, including the extent of environment degradation, the impact of this degradation on livelihoods and social cohesion or the availability of services and infrastructure.

The Climate Vulnerability Assessment aims to address this evidence gap, providing a more comprehensive and thematic assessment of locations of origin (that is, locations that have already recorded displacement as a result of climate change and environmental degradation). Through this pilot, the assessment aims to build an evidence base on the conditions in areas that have already recorded displacement, and to support identification of trends which indicate that locations and communities may be vulnerable to displacement in the future.

The first section of this report presents an overview of climate-induced displacement in central and southern Iraq, analysing displacement flows, depopulation figures, time trends and fully abandoned locations. The next section discusses the top drivers of climate-induced depopulation,[53] such as the presence of multiple water issues, food insecurity and difficulties accessing services and infrastructure. The prevalence of different slow onset and extreme weather events, including drought, sand or dust storms and increased water salinity, is considered in the following section, alongside factors contributing to a reduction in the irrigation water supply. The report then describes challenges accessing basic services and infrastructure, especially water for drinking and domestic use. The impact of climate change and environmental degradation on land- and water-based livelihoods is assessed in the subsequent section, together with the adoption of mitigation measures to cope with these changes. Thereafter, the report explores the relationship between natural resources and tension and conflict, highlighting the actors and resources involved, consequences and changes over time. Lastly, remote sensing data on changes in vegetation health are evaluated in locations reporting high levels of climate-induced depopulation.

35 The United Nations Office for Disaster Risk Reduction defines natural hazards as 'natural processes or phenomena that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage.' United Nations Office for Outer Space Affairs, 'Risks and disasters' (n.p., n.d.).

36 IOM, *IOM Perspectives on Migration, Environment and Climate Change* (Geneva, n.d.).

37 Intergovernmental Panel on Climate Change, *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, Cambridge University Press (Cambridge and New York, 2018).

38 IOM, 'Environmental migration' (Geneva, n.d.).

39 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).

40 Between 1970 and 2004, Iraq's yearly average temperature has risen by 1-2 degrees Celsius. World Bank Group, *Iraq: Systematic Country Diagnosis* (n.p., 2017).

41 Rainfall is expected to drop 25 per cent by 2050. Theodore Karasik and Jacopo Spezia Depretto, 'Climate change is exacerbating Iraq's complicated water politics,' *Climate Diplomacy* (Berlin, 2019).

42 Based on the World Resources Institute's Water Stress Index, Iraq is expected to reach 4.6 out of 5 points, with 5 reflecting the greatest degree of water scarcity. Andrew Maddocks, Robert Samuel Young & Paul Reig, 'Ranking the world's most water-stressed countries in 2040,' *World Resources Institute* (n.p., 2015).

43 Ibid.

44 United Nations Country Team in Iraq, Joint Analysis and Policy Unit, *Sand and Dust Storms Fact Sheet* (Baghdad, 2013).

45 REACH, United Nations Children's Fund and United Nations Institute for Training and Research (UNITAR), *Flood Hotspots in Iraq (October 2018–March 2019)* (Baghdad, 2020).

46 Saleem A. Salman, Shamsuddin Shahid, Tarmizi Ismail, Eun-Sung Chung and Alaa M. Al-Abadi, Long-term trends in daily temperature extremes in Iraq, *Atmospheric Research* 198(6) (August 2017).

47 Iraq's drinking, sanitation and irrigation water comes almost entirely from the Tigris and Euphrates rivers. By 2030, flows in these rivers are anticipated to fall by 50 per cent, largely as a result of water management practices in neighbouring countries such as Türkiye and the Islamic Republic of Iran. Pieter-Jan Dockx, Water scarcity in Iraq: From inter-tribal conflict to international disputes, *Institute of Peace and Conflict Studies* (n.p., 2019).

48 Tobias Von Lossow, More than infrastructures: water challenges in Iraq, *Planetary Security Initiative and Clingendael* (n.p., 2018).

49 Ibid.

50 IOM, *Iraq – Displacement Tracking Matrix (DTM) – Climate Methodology* (Baghdad, n.d.).

51 Ibid.

52 Ibid.

53 Climate-induced depopulation refers to the share of the original population displaced by climate change or environment degradation. Climate-induced displacement, in contrast, refers to the absolute numbers of people displacing.

# METHODOLOGY

The assessment takes the form of key informant interviews conducted by IOM's Rapid Assessment and Response Teams (RARTs), who are deployed across Iraq (20% of enumerators are female). IOM RARTs collect data utilizing a large and well-established network of KIs, including community leaders, mukhtars, local authorities and security forces.

Locations targeted for Climate Vulnerability Assessment have been identified by DTM Iraq's RARTs from the ET caseload as the locations of origin of families displaced due to environmental factors, including droughts, increased water salinity, biodiversity loss, soil degradation, changing rainfall patterns, increased temperature, sand/dust storms and landslides.

Families displaced by environmental factors are grouped separately from those displaced by the 2014–2017 conflict. In the rare instances where families were displaced by both the conflict and environmental conditions, these families are included in both the climate displacement caseload and the conflict displacement caseload. Such is the case in Diyala Governorate, where some families were displaced by the conflict with the Islamic State in Iraq and the Levant then returned to their area of origin, only to be re-displaced by drought.

This pilot round collected data between August and October 2022 from 262 locations of origin containing 9,215 families in 29 districts across nine governorates of Iraq, who represent 88 per cent of the climate migrant caseload according to September 2022 ET data. This monitoring exercise focuses on governorates in the central and southern regions of Iraq, along with Diyala, as climate-induced displacement has primarily been observed in these governorates.

Location-level data have then been aggregated to identify trends or areas of concern at the district level. IOM key informants' data have also been triangulated with geospatial data, namely normalized difference vegetation index (NDVI) anomaly data, which measure changes in the health of vegetation compared to the long-term average. These data were analysed in partnership with the World Food Programme (WFP).

## DEFINITIONS AND INDICATORS

### ENVIRONMENTAL AND CLIMATE MIGRATION

There is currently no legal or internationally accepted definition for people moving in response to environmental factors. Nonetheless, in 2007, IOM developed a working definition of 'environmental migrants,' which highlights the diversity of environmental triggers for movement, the varying lengths of time for such movement, the degree to which these movements are voluntary and the potential destinations for these individuals.

'*Environmental migrants are persons or groups of persons who, predominantly for reasons of sudden or progressive change in the environment that adversely affects their lives or living conditions, are obliged to leave their habitual homes, or choose to do so, either temporarily or permanently, and who move either within their country or abroad.*'[54]

Climate migration forms a subset of environmental migration, with individuals leaving their habitual place due to changes in the environment linked to climate change. In particular, climate migration refers to:

'*The movement of a person or groups of persons who, predominantly for reasons of sudden or progressive change in the environment* due to climate change, *are obliged to leave their habitual place of residence, or choose to do so, either temporarily or permanently, within a State or across an international border* (emphasis added).'[55]

This assessment focuses on families 'displaced… due to drought, water scarcity or other climate-related factors since 2016.'[56] In other words, it targets a subset of migrants who were forced to move due to climactic conditions. Accordingly, the report will refer to this phenomenon as climate-induced displacement, in keeping with the assessment's focus, and the broader umbrella term of environmental migration.

### ENVIRONMENTAL DEPOPULATION RATE

| | |
|---|---|
| Low | District where 0–10% of the original population has left due to environmental issues |
| Medium | District where 11–40% of the original population has left due to environmental issues |
| High | District where 41–100% of the original population has left due to environmental issues |

### ENVIRONMENTAL ISSUES

Issues include the presence of: 1) droughts, 2) increased water salinity, 3) biodiversity loss, 4) soil degradation, 5) changing rain fall patterns, 6) increased temperature, 7) sand or dust storms and 8) landslides.

| | |
|---|---|
| Low | Presence of 0–2 environmental issues |
| Medium | Presence of 3–5 environmental issues |
| High | Presence of 6–8 environmental issues |

### WATER ISSUES

Issues include: 1) decrease in water supply, 2) damming or river diversion, 3) reduced rainfall patterns, 4) broken or inefficient water infrastructure, 5) reduced water allocation, 6) reduced water quality (e.g. salinity, pollution), 7) population growth and/or agricultural intensification and 8) rising costs of water trucking.

| | |
|---|---|
| Low | Presence of 0–2 water issues |
| Medium | Presence of 3–5 water issues |
| High | Presence of 6–8 water issues |

### LACK OF ACCESS TO SERVICES AND INFRASTRUCTURE

Issues include: 1) less than 76 per cent of households have enough electricity for their needs; 2) less than 76 per cent of households have enough water for their drinking and domestic needs; 3) reliance on water trucking (sometimes or always); the following services and infrastructure not being functional or accessible within five kilometres: 4) primary school, 5) secondary school, 6) health services or 7) markets; and 8) have not received aid/assistance.

| | |
|---|---|
| Low | Presence of 0–2 issues related to infrastructure or services |
| Medium | Presence of 3–5 issues related to infrastructure or services |
| High | Presence of 6–8 issues related to infrastructure or services |

54 IOM, *Discussion Note: Migration and the Environment* (MC/INF/288 of 1 November 2007), prepared for the Ninety-Fourth Session of the IOM Council (Geneva, 2007).
55 IOM, *International Migration Law No. 34, Glossary on Migration* (Geneva, 2019).
56 IOM, Iraq – Displacement Tracking Matrix – Location-Based Climate Vulnerability Assessment Questionnaire [publication forthcoming].

### LACK OF ACCESS TO LIVELIHOODS

Issues include: 1) reliance on land including commercial farming, smallholder farming, livestock rearing or transhumance; 2) reliance on water including fishing or fish farming; 3) loss of crops; 4) abandoned agriculture/livestock/fishing activities in classes (more than 50% of households); 5) unable to meet food needs (more than 50% of households); 6) struggle to feed livestock; 7) no access to grazing land or access to land of poor quality or rising price for fodder and 8) adopted mitigation measures, including migration.

| | |
|---|---|
| Low | Presence of 0–2 issues related to livelihoods |
| Medium | Presence of 3–5 issues related to livelihoods |
| High | Presence of 6–8 issues related to livelihoods |

### TENSION OR CONFLICT

Issues include: 1) presence of tension/conflict between groups, 2) tensions/conflict are related to natural resources (one point for one resource and two points for more than one), 3) the number of groups involved in tension/conflict (with one point for one group involved and two points for two or more groups), and 4) tensions/conflict are increasing.

| | |
|---|---|
| Low | Presence of 0–2 issues related to tension or conflict |
| Medium | Presence of 3–4 issues related to tension or conflict |
| High | Presence of 5–6 issues related to tension or conflict |

### RANDOM FOREST METHODOLOGY

To understand the leading drivers of climate-induced displacement, a Random Forest classification algorithm was used. Random Forest is based on the Decision Tree model, a type of machine learning algorithm that ranks different predictors based on their level of association with the dependent variable and sorts observations into groups based on shared traits. Decision Tree analysis can be used to classify locations based on the most relevant independent variables and predict which category locations might fall into based on those characteristics. The Random Forest builds a set of uncorrelated Decision Trees (a forest) and ranks the predictors used in each tree based on the mean decrease in the Gini coefficient. This approach addresses issues of multicollinearity and overfitting associated with a single Decision Tree.

The dependent variable for the Decision Trees composing the Random Forest was 'rate of depopulation' (that is, the portion of the original population displaced), grouped as follows: 'low' depopulation (0–10%), 'medium' depopulation (11–30%) and 'high' depopulation (31–100%). In total, 28 independent variables were tested through the Random Forest analysis.

Although the Random Forest addresses issues of multicollinearity in terms of prediction, more caution is needed with respect to the score of factors. If two or more variables are correlated and one is selected for the model, the other variables will most likely not be selected. This is because the correlated variable(s) do not offer additional explanatory power for the model. As a result, the importance of the two or more correlated variables is weakened. The top predictors of climate-induced depopulation should therefore be viewed holistically, without placing significant emphasis on the magnitude of difference between each score.

A complete description of the model development and methodology can be found in the Annex.

## CHALLENGES AND LIMITATIONS

### LOCATIONS OF ORIGIN FOR CLIMATE-INDUCED DISPLACEMENT

Many of the locations of origin targeted for this assessment have not previously been assessed by DTM Iraq. As a result, the first round of data collection should be considered a pilot round, with RARTs identifying as many locations of origin for affected families as possible and identifying suitable KIs in each location to report on movements and living conditions. Given the operational complexity of identifying locations for this assessment and the remoteness of some locations of origin, not all locations of origin were assessed in the pilot round.

Furthermore, due to ongoing environmental programming in Al-Shatra district, locations in other districts were prioritized for assessment, in coordination with the Ministry of Migration and Displacement. As a result, Al-Shatra was not assessed, although it is as a district of origin and displacement for climate migrants according to the Climate ET data.

### LOCATION-LEVEL DATA

All data collected in the Climate Vulnerability Assessment were collected at location level. This means that KIs were interviewed about the conditions faced in locations of origin for climate-displaced families. These locations correspond to a village for rural areas or, less commonly, a neighbourhood for urban areas (that is, the fourth administrative division). While this approach allows extensive coverage over a short period of time, it often relies on one informant per location. These KIs are mainly mukhtars and community or local council representatives who report on the views and experiences of a potentially large and diverse population, which might lead to limited representation for smaller groups with distinct characteristics, or discrepancies caused by social desirability bias. Additionally, key household characteristics including sociodemographic indicators (i.e. number of family members) and vulnerability factors (i.e. gender of the head of household or number of members living with a disability) are not accounted for in the datasets.

A specific challenge of location-level data with regards to climate indicators is the complexity of the variables (e.g. the concept of land degradation) and the subjectivity of perceptions with regard to changes in the climate (e.g. unseasonal variations in the temperature). As noted earlier in the section, the assessment addresses this point by triangulating key informants' data with available geospatial data, namely NDVI Anomaly data,[57] in collaboration with WFP's Vulnerability and Analysis Mapping unit.[58]

### GROUPS NOT CONSIDERED WITHIN ASSESSMENT

The Climate Vulnerability Assessment targets locations from which families have already displaced, identifying the vulnerability factors present in each location. However, without including locations from which there has been no climate-induced displacement to date, it is difficult to determine how target locations differ from others in the area or to identify what differentiates locations with displacement from those without it. On the other hand, this assessment did not assess locations that had been fully abandoned. Future versions of this assessment will seek to include such locations, as they may constitute the areas most impacted by climate change and environmental degradation.

57 The NDVI measures the 'greenness' of ground cover and is used as a proxy to indicate the density and health of vegetation. The NDVI anomaly indicates the variation of the current period to the long-term average, where a positive value would signify enhanced vegetation conditions compared to the average, while a negative value would indicate comparatively poor vegetation conditions.

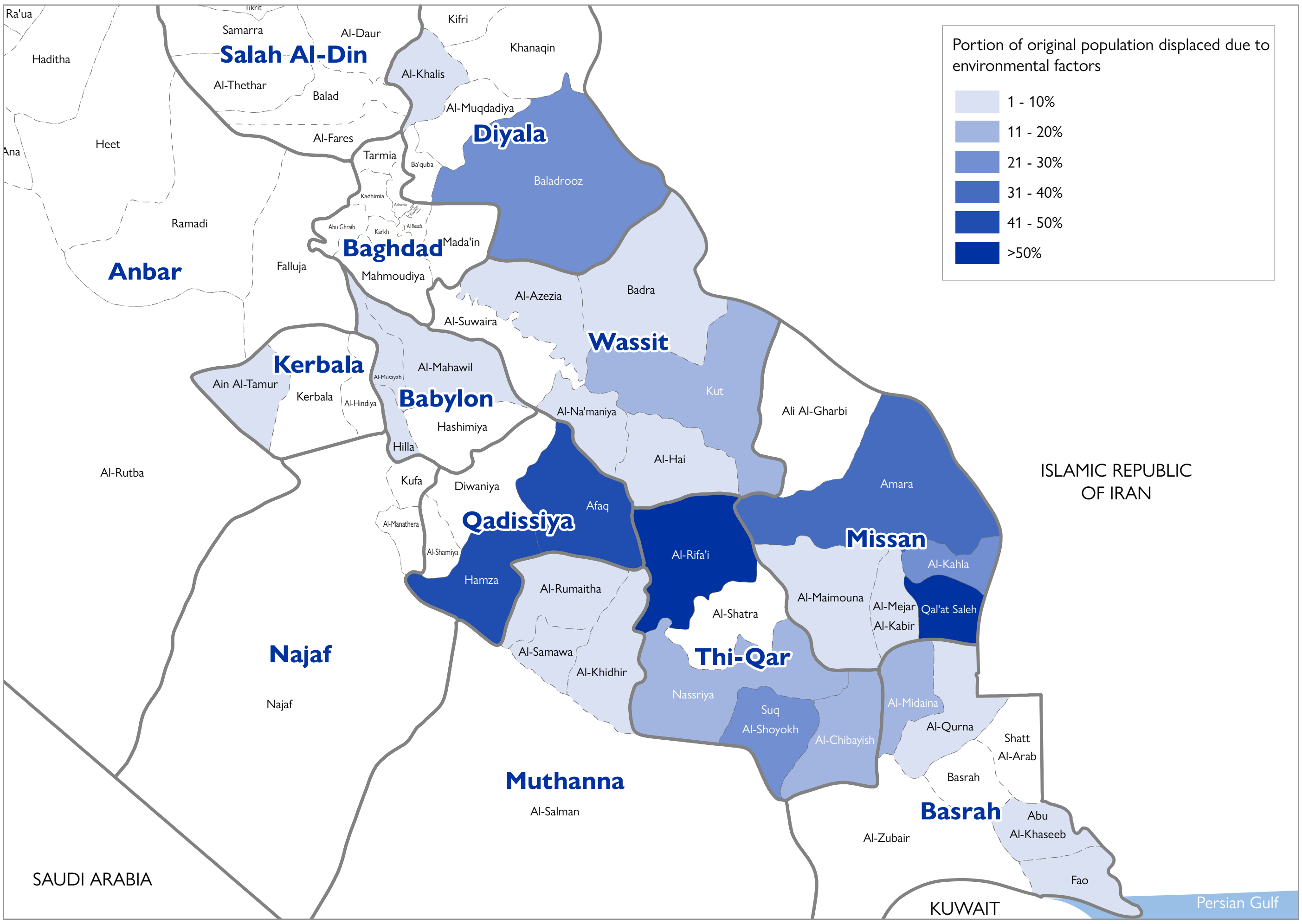
58 The VAM team conduct telephone interviews with around 3,000 households to assess food security and market access across Iraq.

# FINDINGS

## DISPLACEMENT DYNAMICS

This section discusses the scope and magnitude of climate-induced displacement across central and southern Iraq, highlighting districts with high rates of depopulation (Map 2). A small set of locations, concentrated in Thi-Qar Governorate, have been fully abandoned, representing the worst-case scenario. Other trends related to climate-induced displacement are considered through analysis of flows and time trends. Most people are leaving rural areas in favour of urban centres, often within the same governorate. However, some people relocate to other rural areas in order to continue practising land- and water-based livelihoods. Additionally, levels of displacement increased significantly in 2022 compared to prior years, reflecting displacement from new areas as well as elevated displacement from previously identified locations.

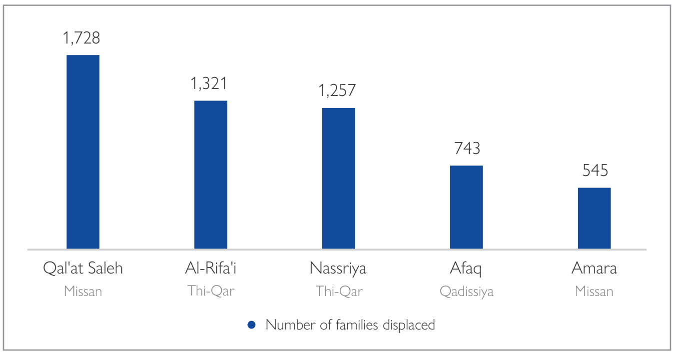
Map 2. Portion of original population displaced due to environmental factors




## SCALE OF DISPLACEMENT

Overall, 9,215 families (55,290 individuals) have displaced due to drought, water scarcity or other climate-related factors between January 2016 and September 2022, representing 15 per cent of the total population who used to live in these locations. In other words, more than 1 in 10 people originally residing in these locations have displaced. The top governorates of origin for climate migrants are Thi-Qar (2,812 families) and Missan (2,719), followed by Muthanna (975) and Qadissiya (950). At the district level, the largest number of climate migrants left from Qal'at Saleh in Missan Governorate (1,728 families), along with Al-Rifa'i (1,321 families) and Nassriya (1,257 families) in Thi-Qar Governorate (Figure 3).

Figure 3. Districts with the highest number of families displaced due to environmental conditions



In around two thirds of locations, over one in five people had already left due to environmental issues at the time of the assessment. The governorates with the highest rates of depopulation are Qadissiya (44%), followed by Kerbala (31%), Thi-Qar (27%) and Missan (25%). Among districts, depopulation is highest in Al-Rifa'i, Thi-Qar Governorate (61%); Qal'at Saleh, Missan Governorate (51%); Afaq (44%) and Hamza (42%), both in Qadissiya Governorate, and Amara, Missan Governorate (32%) (Figure 4). Ten locations, most of which in Thi-Qar Governorate, are completely abandoned due to climate-related issues (Table 1).

Figure 4. Districts with highest portion of population displaced

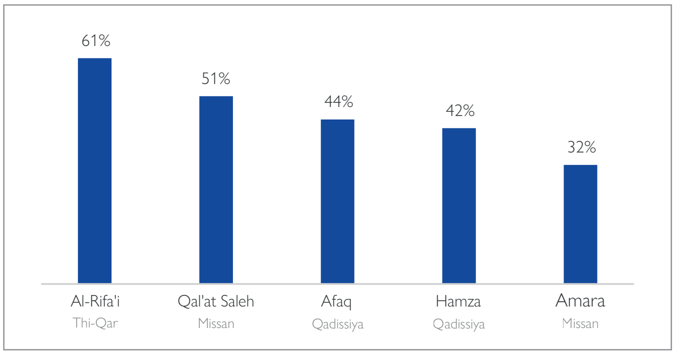



Table 1. Number of locations completely abandoned by district

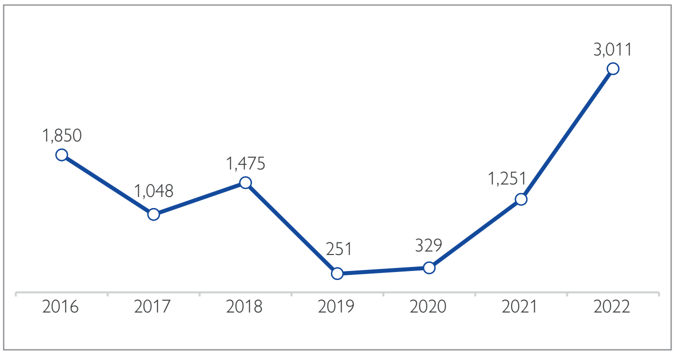
| District, Governorate | Number of locations |
|---|---|
| Nassriya, Thi-Qar | 5 |
| Suq Al-Shoyokh, Thi-Qar | 3 |
| Al-Mejar Al-Kabir, Missan | 1 |
| Badra, Wassit | 1 |
| **Total** | **10** |

## TRENDS IN CLIMATE-INDUCED DISPLACEMENT

Climate migrants in Iraq often move from **rural to urban** locations. Nearly all (98%) originate from rural areas, while more than half (57%) resettled in urban settings, which may offer more livelihood opportunities. Moreover, individuals displaced by environmental factors tend to **stay close to their location of origin**. According to September 2022 ET data, around two thirds (67%) of people displaced by environmental factors remain within their governorate of origin and a further third (37%) stay within their district of origin. Many families move to nearby urban centres, including the southern governorates' capital cities, such as Amara (Missan), Kut (Wassit) and Nassriya (Thi-Qar), as well as other important urban areas. The only significant exception are rural areas in Najaf, which have attracted a significant number of families from the governorates of Qadissiya and Thi-Qar. Moving to another rural area enables families to maintain their previous livelihoods. For example, some water buffalo herders from the marshes of Thi-Qar relocate to riverine areas of Najaf to continue these practices.[59]

As shown in Figure 5, among the climate migrants identified by DTM since 2016, one third (33%) were displaced between January and September 2022, the highest of any year recorded. Considering these figures do not cover the entirety of 2022, end-of-year figures are likely to be even higher. Displacement in 2022 was especially high in the governorates of Diyala (100%), Babylon (84%), Wassit (77%) and Thi-Qar (62%). Key drivers of movement in these governorates over the past year are low rainfall and low water levels in rivers and tributaries. Additional aggravating factors include low levels of groundwater, water salinization, disputes over water allocation and restrictions on the use of water. In Basra, Kerbala, Missan and Muthanna, by contrast, most displacement took place before 2019.

Figure 5. Number of climate migrants by year of displacement, as of September 2022




Environmental issues may also hinder returns of people displaced due to the conflict with the Islamic State of Iraq and the Levant. Although an uncommon occurrence, 2 per cent of internally displaced households, most of whom originate from Al-Khalis district in Diyala Governorate, re-displaced upon return to their district origin due to drought, water scarcity or other climate factors.

## DRIVERS OF CLIMATE-INDUCED DEPOPULATION

This section explores the top five drivers of climate-induced depopulation (that is, the share of the original population who are displaced) through Random Forest analysis[60] (Figure 6). These drivers, which include the presence of multiple water issues, food insecurity, difficult access to services and infrastructure, reliance on land for livelihoods and adoption of mitigation measures, reflect the relationship between environmental and economic challenges in central and southern Iraq. Reduced water quantity and quality, triggered by a wide range of factors at the international, national, governorate and community levels, are making climate-sensitive livelihoods increasingly difficult to sustain and preventing people from meeting their basic needs. Families engaged in farming, livestock rearing and fishing depend on water resources and conducive environmental conditions to make a living. A reduction in income from these livelihoods means families are struggling to afford essential items like food and are adopting mitigation measures to cope with these changes. At the community level, locations of origin are failing to provide residents with the resources needed to adapt to these changes through the provision of services and infrastructure. This analysis suggests that at the moment of displacement, families are in precarious economic positions and see few alternatives other than relocation.

The **strongest predictor of climate-induced depopulation was the presence of multiple water issues** in a location, such as reduced rainfall, lower water allocation and broken or inefficient water infrastructure. As some water issues were common to nearly all locations, especially reduction in irrigation water sources, decrease in rainfall and reduced water quality, these factors were less useful for predicting depopulation. In contrast, issues related to the **cost of water trucking** and **damming or river diversions appear to have a greater influence on depopulation.**

These drivers highlight the multifaceted nature of Iraq's water crisis, which is impacted by climactic factors but also local, national and international water management policies. Additionally, issues related to the cost of water trucking suggests more remote rural locations are affected, as long-distance transportation can increase the price of these services. Moreover, without alternative sources

59 Based on notes from DTM RARTs.
60 For more information on this analysis, please see the Methodology and Annex.

of water, families practising agriculture and livestock rearing will depend more heavily on water trucking. Greater reliance on water trucking translates into higher costs for families. Finally, families facing challenges related to the cost of water trucking are likely those who are struggling to afford it, thus underscoring the relationship between environmental and economic challenges.

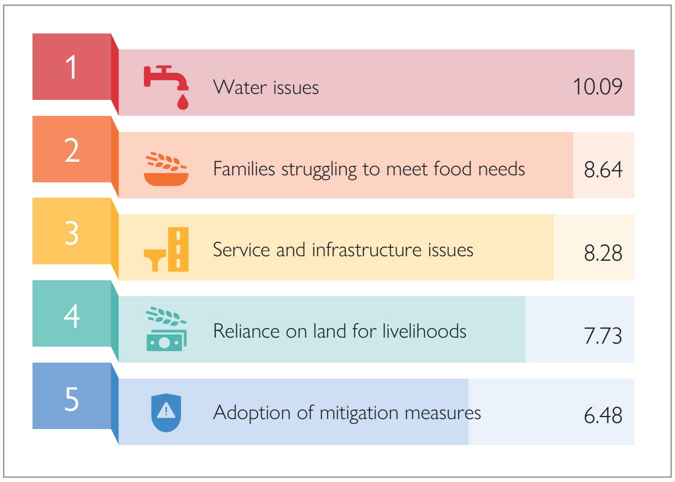
**Food insecurity**, or, more precisely, half or more households in a given location struggling to meet their basic food needs, is the second strongest predictor of climate-induced depopulation. Climate change and environmental degradation can contribute to food insecurity by decreasing crop yields and herds. This reduced supply, along with greater reliance on imports, can raise the price of food.[61] The relationship may also be indirect, with climate change resulting in reduced agricultural production and thus fewer livelihood opportunities in a traditionally labour-intensive industry. Unemployment and lower household income, in turn, increases the risk of food insecurity.[62] Other non-environmental factors observed in recent months, such as depreciation of the Iraqi dinar and consumer price inflation, have also driven up the price of food.[63] The connection between food insecurity and climate-induced depopulation emphasizes the economic issues driving this trend. If food insecurity is contributing to displacement, this indicates that families in the locations of origin are not earning enough to meet their most essential needs.

The third strongest predictor of depopulation is **difficult access to services or infrastructure**. This flags the challenges faced by remote rural locations, where access to education, health care and markets is constrained. Given the health- and energy-related impacts of climate change,[64, 65] difficult access to services impedes the ability of families to cope with worsening environmental conditions. Additionally, challenges accessing secondary education can limit job prospects, thus reinforcing communities' reliance on climate-sensitive livelihoods, such as agriculture, livestock rearing, pastoralism and fishing.

**Reliance on land for livelihoods** is the fourth strongest predictor of the depopulation rate. For farmers, climate change and environmental degradation contribute to reduced crop yields through increased temperatures, decreased water supply, reduced water quality and pests, among other factors.[66] For livestock rearers, negative environmental changes are eroding the quality of grazing land and leading to higher costs for fodder. This makes it more difficult to feed livestock, resulting in more deaths. Reduced yields and herds translate into less income for farmers and livestock rearers, causing growing numbers to abandon these practices altogether. In the absence of alternative livelihood options in their locations of origin, families must relocate in search of new job opportunities. In some cases, families sell their farms or livestock to fund the journey, making it more difficult to return and resume these activities if environmental conditions improve.[67]

The fifth strongest predictor of depopulation is the **adoption of mitigation measures** by families, reinforcing the links between environmental and economic challenges. The adoption of mitigation measures implies that families have been negatively impacted by changes in the environment and are taking steps to overcome these difficulties. The most common mitigation measure is sending household members to another location to make money. This reflects the lack of alternative livelihood opportunities in areas of origin and the reduced income due to decreased yields and herds. Additionally, in many locations, households are lowering their expenditure to cope. This strategy also implies that families are less able to meet their needs. Moreover, selling assets such as land and livestock is another commonly indicated mitigation measure. While this approach generates income in the short term, it reduces the family's wealth and potential earnings from agriculture and livestock rearing in the medium to long term.

Figure 6. Top five predictors of climate-induced depopulation




Note: Based on mean decrease in Gini coefficient from Random Forest analysis

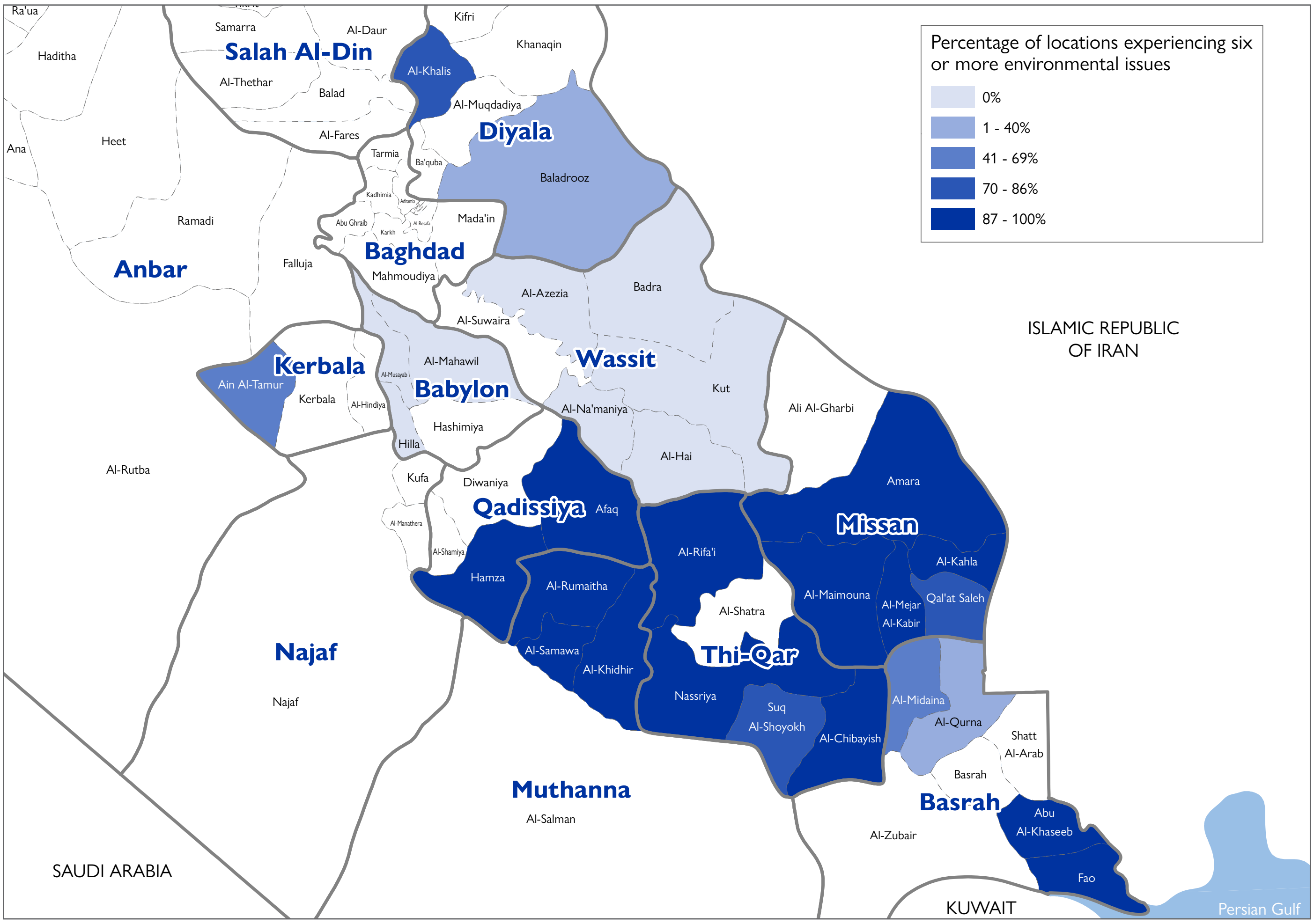
## ENVIRONMENTAL HAZARDS AND WATER ACCESS

Central and southern Iraq are witness to a wide range of slow onset and extreme weather events. Most locations assessed face at least six types of environmental hazards (Map 3), with droughts, sand/dust storms and increased water salinity being the most common. As a result, the quantity and quality of water in Iraq have diminished significantly. In many locations, irrigation water is sourced from rivers, canals and wells. However, this water supply has decreased nearly everywhere as a result of climactic factors and issues related to water governance and management.

61 World Food Programme and Social Inquiry, *Improving Prospects for Peace and Stability in Vulnerable Communities in Southern Iraq. Thi-Qar Governorate Conflict Analysis* (Baghdad, 2022).
62 World Bank Group, *Iraq Economic Monitor – Reemerging Pressures: Iraq's Recovery at Risk* (Spring/Summer 2023, Washington D.C.)
63 Ibid.
64 World Health Organization and United Nations Framework Convention on Climate Change, *Iraq – Health and Climate Change Country Profile 2021* (Geneva, 2021).
65 Mounir Mahmalat and Ali Ahmad, 'In Iraq, mitigating fragility means addressing climate change' [blog post], World Bank Group, 18 April 2023.
66 IOM and Social Inquiry, *A Climate of Fragility – Household Profiling in the South of Iraq: Basra, Thi-Qar and Missan* (Baghdad, 2022).
67 IOM and Social Inquiry, *Migration into a Fragile Setting: Responding to Climate-Induced Informalization and Inequality in Basra, Iraq* (Baghdad, 2022).

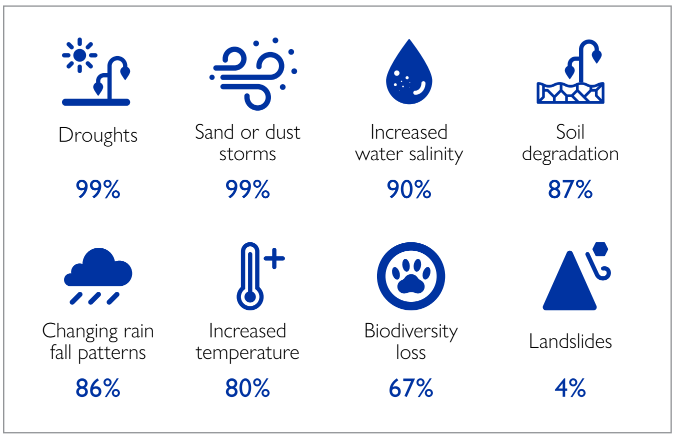
## ENVIRONMENTAL HAZARDS

Map 3. Percentage of locations experiencing six or more environmental hazards in the last three years by district




The most common environmental hazards are **droughts** and **sand/dust storms**, which were reported in nearly all affected locations (99%). **Increased water salinity** and **soil degradation** were also commonly reported (90% and 87%, respectively), especially in the six governorates of Diyala, Missan, Muthanna, Qadissiya, Thi-Qar and Wassit. Additionally, many locations experienced changing rainfall patterns (86%) and increased temperature (80%), particularly in Basra, Diyala, Missan, Muthanna, Qadissiya and Thi-Qar. Biodiversity loss (67%) mostly affects Kerbala, Missan, Muthanna, Qadissiya and Thi-Qar, whereas landslides were reported only in Thi-Qar (16%) and Qadissiya (8%) (Figure 7).

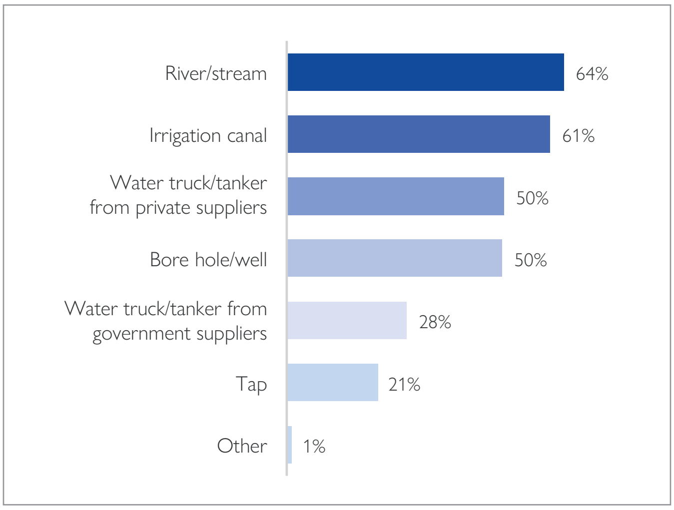
Figure 7. Most prevalent environmental hazards by percentage of locations




## WATER SOURCES FOR IRRIGATION

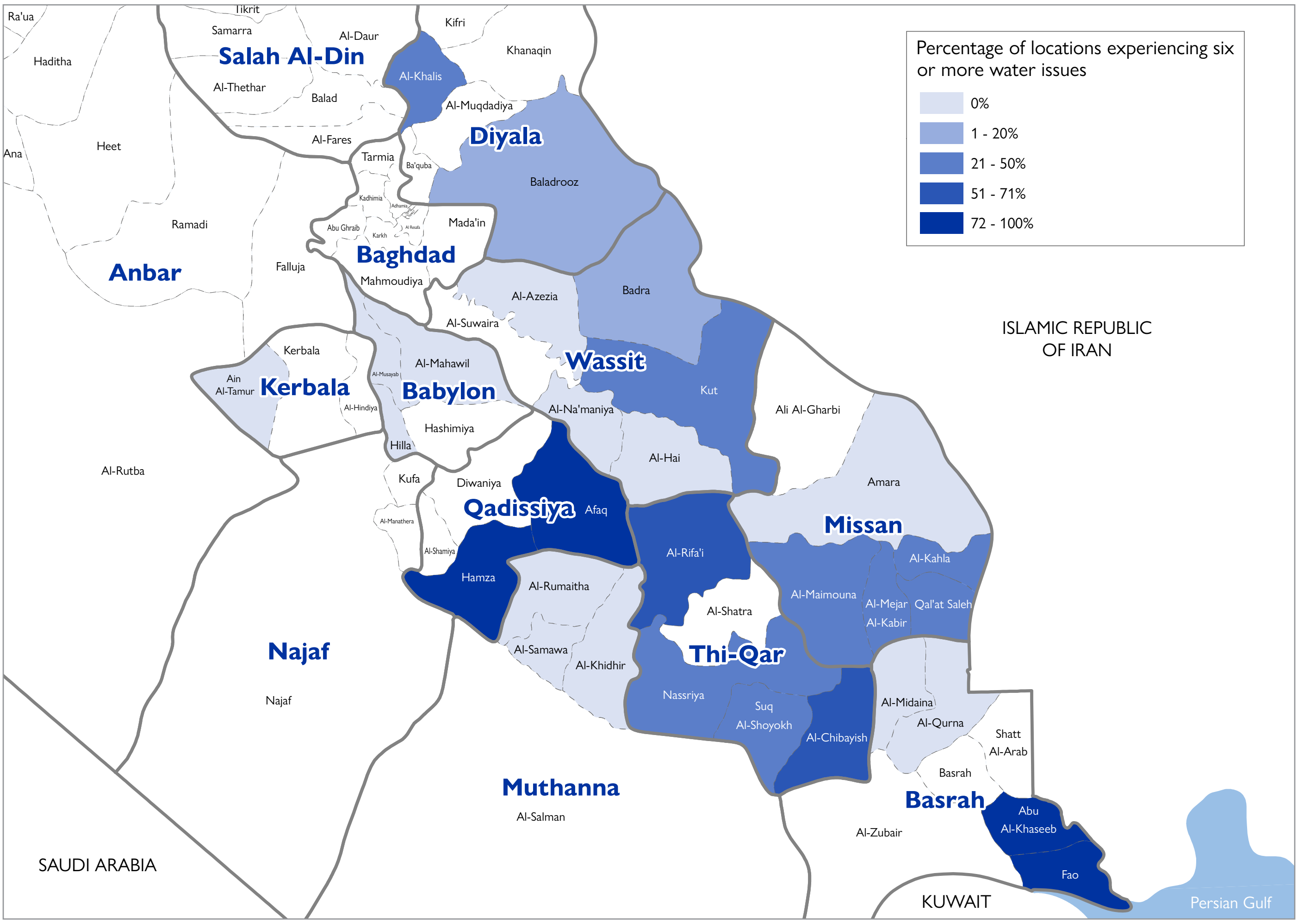
In many locations, families rely on **rivers or streams** (64%), **irrigation canals** (61%) or **bore holes or wells** (50%) to meet their water needs for irrigation. However, **water trucking** – from private suppliers (50%) or the government (28%) – is still necessary in most locations of Thi-Qar, Qadissiya, Missan, Diyala and Wassit governorates (Figure 8).

Figure 8. Most common water sources for irrigation



## CHANGES IN WATER SUPPLY

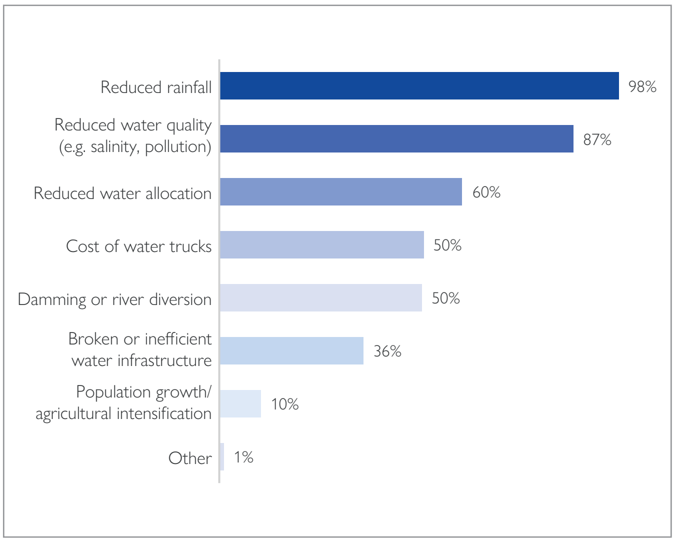
Map 4. Percentage of locations with six or more water issues by district




A **decrease in water supply** was observed in nearly all locations assessed (99.6%). **Reduced rainfall patterns** and **degradation in water quality** (increased water salinity and pollution) were cited as the main drivers of this decrease (98% and 87%, respectively). Data also reveal the impact of **water allocation practices** (60%) and **damming/river diversions** (50%),[68] mainly stemming from a lack of transboundary water sharing agreement between Iraq and its neighbours[69, 70] and perceptions of inequitable water distribution within the country.[71] A higher portion of locations in Qadissiya (92%), Kerbala (92%), Thi-Qar (79%) and Missan (72%) attributed the decreased supply of water to reduced allocation.

Ineffective water management (that is, broken or inefficient water infrastructure, such as canals that suffer from evaporation or wasteful irrigation methods) was reported in over one third of locations (36% overall), with peaks in Qadissiya (96%) and Missan (81%). In half of locations (50%), KIs linked the decrease in water supply to the costs of water trucking and in 10 per cent of locations to population growth or intensive agriculture techniques (largely in Diyala and Kerbala governorates) (Figure 9).

Figure 9. Percentage of locations by water supply issues




68 As part of its Anatolia Project, Türkiye has constructed 22 dams on the Tigris and Euphrates rivers. The Islamic Republic of Iran also redirects tributaries from these rivers as part of its water supply. Within Iraq, the Kurdistan Regional Government entered into an agreement with a private company to construct four dams. Nussaibah Younis, Early warning: How Iraq can adapt to climate change, *European Council on Foreign Relations* (Berlin, 2022).

69 Bilateral water sharing agreements between Iraq and its neighbours exist but have been ignored or violated. Mervyn Piesse, Water governance in the Tigris-Euphrates Basin, *Future Directions International* (Dalkeith, 2016).

70 Roger Guiu, *When Canals Run Dry: Displacement Triggered by Water Stress in the South of Iraq*, Internal Displacement Monitoring Centre, Social Inquiry and the Norwegian Refugee Council (Baghdad, 2020).

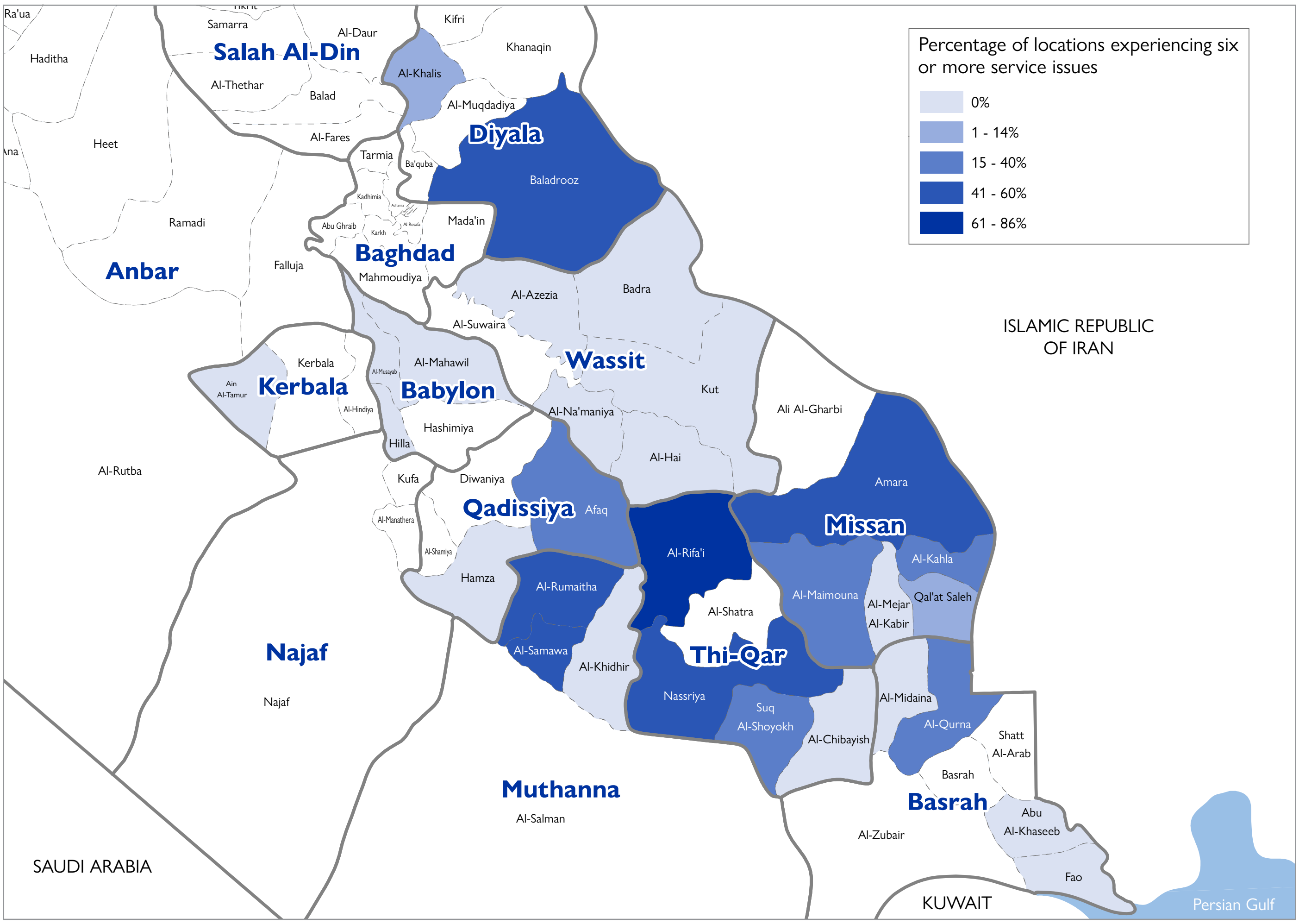
71 Missan and Kut have experienced tensions over water sharing due to the perception by downstream governorates that upstream governorates were exceeding their allocation of water. Additionally, disputes have arisen between Muthanna, Qadissiya and Thi-Qar governorates for similar reasons. Nussaibah Younis, Early warning: How Iraq can adapt to climate change, *European Council on Foreign Relations* (Berlin, 2022).

Reduced water levels have important implications for water quality. In Basra, for example, decreased water flows in the Shatt al-Arab waterway, along with the intrusion of sea water from the Persian Gulf, have contributed to a three-fold increase in the waterway's salinity in the last 50 years. Increased salinity and pollution of water, in turn, led to the hospitalization of 118,000 people between August and November 2018.[72]

## ACCESS TO SERVICES AND INFRASTRUCTURE

This section evaluates access to eight services, including electricity, water for drinking and domestic use, primary and secondary school, markets and health services (Map 5). It also assesses the extent to which families rely on water trucking and whether families in the location have received any assistance in the past year. As described further below, difficulties accessing services and infrastructure are widespread but are especially pronounced in Thi-Qar. In line with the findings of the previous section, water is the most difficult service to access.

Map 5. Percentage of locations with six or more service issues by district



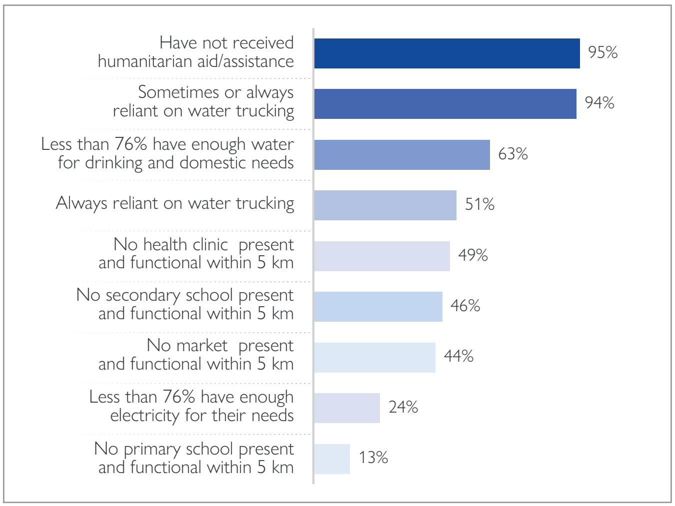

Access to services and infrastructure appears to be **challenging in nearly all assessed locations**. KIs reported that no locations have adequate access to all eight screened indicators. Additionally, nearly 9 out of 10 locations faced at least three service-related issues (63% experiencing 3–5 service issues and 25% experiencing 6–8 issues).[73] In Thi-Qar, 45 per cent of locations have inadequate access to all or nearly all screened indicators. At the district level, **Al-Rifa'i** in Thi-Qar, **Baladrooz** in Diyala, **Amara** in Missan, **Nassriya** in Thi-Qar and **Al-Samawa** in Muthanna reported the highest portions of locations lacking access to all or nearly all services.

The most difficult domains appear to be **water** and **aid/assistance**. In 94 per cent of locations, households have to rely on water trucking, either always (51%) or sometimes (43%). At the governorate level, 100 per cent of locations in Missan and 97 per cent of locations in Thi-Qar always rely on water trucking. Additionally, in 63 per cent of locations, less than 76 per cent of households had enough water for drinking and domestic needs. With respect to aid, 95 per cent of locations have not received any assistance in the past 12 months from the government, humanitarian organizations, local charities or relatives or friends.

Beyond water and humanitarian aid, around half of locations do not have access to functional secondary schools, markets and health centres within five kilometres (46%, 44% and 49%, respectively). More positively, electricity sufficiency and access to primary school are generally within most households' reach (76% and 87%, respectively) (Figure 10).

72 Human Rights Watch, *Basra is Thirsty: Iraq's Failure to Manage the Water Crisis* (n.p., 2019).
73 Data were synthetized in a composite index to better understand access to infrastructure and services. For a full description of indicators selected and related inadequacy thresholds, please refer to the Methodology.

Figure 10. Top service-related issues by percentage of locations

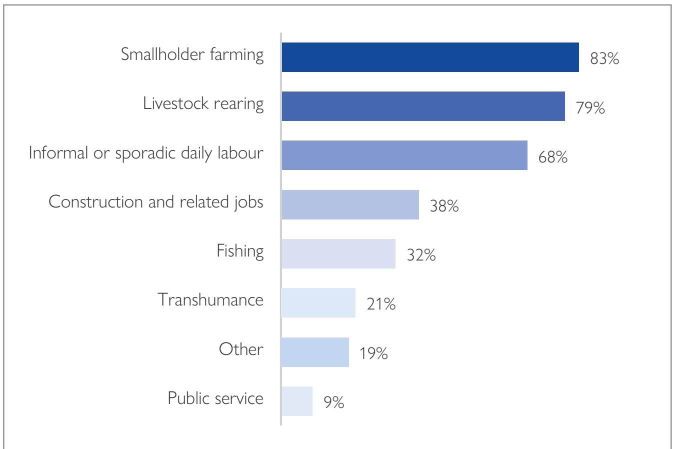



## LIVELIHOODS AND MITIGATION MEASURES

This section describes the economic impacts of climate change and environmental degradation in assessed locations. In many locations, families rely on land- and water-based livelihoods but have experienced decreased yields and herds in the last year. As a result, notable portions cannot afford enough food and must adopt mitigation measures to cope with environmental changes and reduced income. The most common mitigation measure is sending a household member to another location for work, which reflects the role of migration as an adaptation strategy to climate change. Other frequently reported mitigation measures, such as reducing household expenditure, emphasize families' precarious financial position. In some cases, people are abandoning agricultural, livestock rearing and fishing livelihoods altogether. However, in the absence of alternative job opportunities, these families will have no choice but to relocate in search of work.

Across assessed locations, the top livelihood activities include **smallholder farming** (83% of locations), **livestock rearing** (79%) and **informal or sporadic daily labour** (68%). Additionally, construction (38%), fishing (32%) and transhumance (21%) are also commonly practised (Figure 11). Thus, many families are engaged in livelihoods that depend on land and water resources, making them vulnerable to changes in the environment. To a limited extent, the public sector has absorbed some individuals who are unable to maintain agricultural, livestock rearing or fishing activities.[74] In this assessment, only 9 per cent of locations report public service as a primary livelihood.

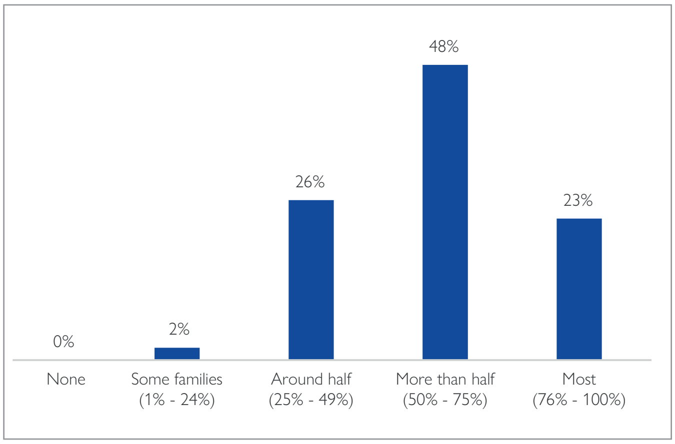
Figure 11. Top livelihoods in districts of origin




Access to livelihoods appears to be relatively challenging in nearly all assessed locations. Across the eight indicators assessed, more than three quarters (77%) of locations faced 6–8 livelihood-related issues. Only 1 per cent of locations experienced two or fewer issues.[75] In Wassit, Qadissiya, Missan and Basra, most locations have inadequate access to all or nearly all screened indicators (100%, 96%, 94% and 91%, respectively).

Among these issues, most locations reported that households experienced **loss of crop production, livestock deaths or reduced fishing yields** due to environmental factors (99%), **struggled to feed livestock** (98%) and/or **resorted to mitigation measures** (75%). As a result of these challenges, in 71 per cent of locations, over half of households **abandoned agriculture, livestock or fishing activities**. Notably, more than 75 per cent of families stopped practising these trades in all locations in Fao district, Basra Governorate and Hamza district, Qadissiya Governorate (Figure 12). Additionally, in 51 per cent of locations, more than half of households **struggled to meet food needs**, especially in Al-Na'maniya and Badra district in Wassit Governorate and Qal'at Saleh in Missan Governorate.

Figure 12. Portion of locations abandoning agriculture, livestock or fishing activities



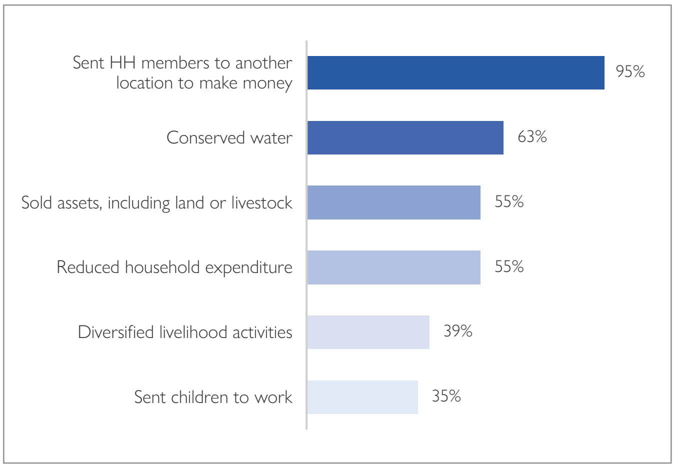

### MITIGATION MEASURES

In locations where households adopted mitigation measures, sending one or more household members to another location for work was the most common approach, as reported in 95 per cent of locations. Families also decreased consumption by conserving water (as recorded in 63% of locations) and reducing household expenditures (55%). Particularly alarming mechanisms include pulling children from school (11%) or sending them to work (35%), as lower educational attainment can have long-term consequences such as diminished employment prospects (Figure 13). Sending children to work was most frequently recorded in the governorates of Wassit (90%), Basra (67%) and Qaddisiya (52%). Basra also had the highest portion of locations in which families pulled children from school (67%).

74 Roger Guiu, *When Canals Run Dry: Displacement Triggered by Water Stress in the South of Iraq*, Internal Displacement Monitoring Centre, Social Inquiry and the Norwegian Refugee Council (Baghdad, 2020).

75 Data were synthetized in a composite index to better understand access to livelihoods. For a full description of indicators selected and related inadequacy thresholds, please refer to the Methodology.

Figure 13. Mitigation measures by portion of locations



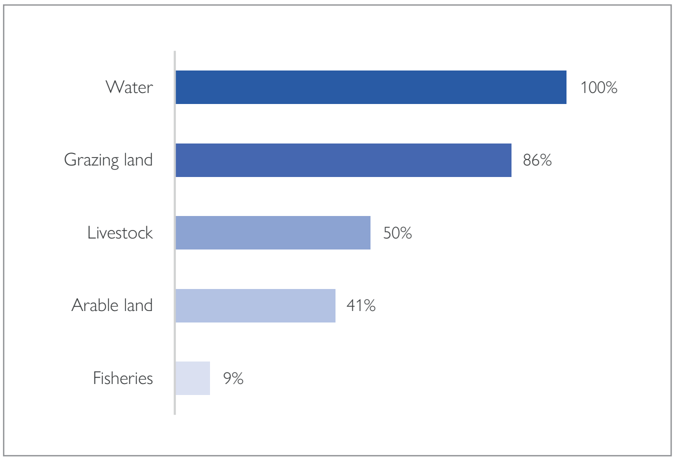

## TENSION AND CONFLICT

Climate change and environmental degradation have the potential to undermine both vertical social cohesion[76] (that is, citizens' trust in the government and authorities) and horizontal social cohesion[77] (that is, trust between citizens from different groups or backgrounds).[78] With respect to vertical social cohesion, poor water quality has triggered protests against authorities in Basra and Thi-Qar governorates and constituted an important grievance among citizens during protests in 2019.[79, 80, 81] In terms of horizontal social cohesion, disputes over access to arable land and water resources have contributed to clashes between farmers, fishers and livestock herders, as well as between tribes.[82]

Based on this assessment's findings, tension and conflict over natural resources appear to be a localized issue, reported in only seven districts. Individuals practising the same livelihoods, often within the same tribe or ethnic group, are experiencing tensions related to water, land and livestock. In most cases, these disputes result in verbal confrontation but in select locations, confrontations have triggered displacement. Increased competition over natural resources in the past year suggest the risk of such tensions growing in the near-term.

In just under a quarter of locations, tensions (18%) or open conflict (4%) between the different population groups were reported, mainly between groups of the same tribe or ethnic descent sharing the same livelihoods.[83] Natural resources were a driver of tension or conflict in only seven districts, especially Nassriya, Kut and Suq Al-Shoyokh. In these areas, tensions primarily revolved around water (100%), grazing land (86%), livestock (50%) and arable land (41%) (Figure 14). A common source of tension was disagreements over water sharing, especially towards farmers who were perceived to have exceeded their water quota for agriculture.[84] Over the last 12 months, competition for natural resources has increased in 82 per cent of these locations. The most frequently reported consequences of these tensions were verbal confrontation (88%), although procurement of weapons (20%), displacement (14%) and open conflict (13%) were indicated in a minority of locations.

Figure 14. Natural resources contributing to tensions among locations affected by this issue




The most problematic district appears to be Al-Qurna in Basra, with KIs reporting 5–6 issues in around one third of locations.[85] Results also indicate an environmental-stressed situation in the three districts of Al-Midaina, Basra Governorate and Nassriya and Suq Al-Shoyokh in Thi-Qar Governorate.

76 The United Nations Development Programme (UNDP) defines vertical social cohesion as 'the degree of trust in national, subnational, or local governments and institutional processes, e.g. elections, access to justice and public services. It is reflected in the ability of governments to ensure effective service delivery, promote inclusive political processes and public policies, and the trust, legitimacy and confidence that citizens ascribe to governments, institutions and political processes.' UNDP, Social Cohesion Hub, *UNDP Conceptual Framework of Social Cohesion* (n.p., n.d.)

77 UNDP defines horizontal social cohesion as 'the sense of trust, relationships and interactions among citizens across different identities or other social constructs, and in the way that social organizations, civil society and social institutions exhibit a sense of interdependency and 'common destiny'. Ibid.

78 Laura Birkman, Dorith Kool and Eva Struyken, *Water Challenges and Conflict Dynamics in Southern Iraq: An In-Depth Analysis of an Under-Researched Crisis*, Water, Peace and Security (n.p., 2022).

79 Human Rights Watch, *Basra is Thirsty: Iraq's Failure to Manage the Water Crisis* (n.p., 2019).

80 IOM, Conflict and Environmental Degradation in Iraq's Dhi Qar Governorate (Baghdad, 2023) [internal publication].

81 Laura Birkman, Dorith Kool and Eva Struyken, *Water Challenges and Conflict Dynamics in Southern Iraq: An In-Depth Analysis of an Under-Researched Crisis*, Water, Peace and Security (n.p., 2022).

82 Ibid.

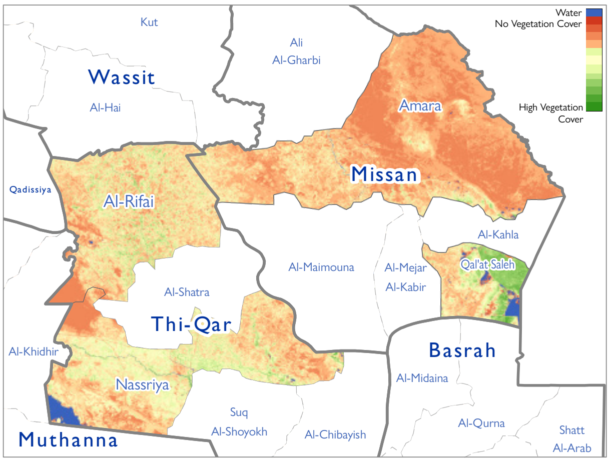
83 Data were synthetized in a composite index to better understand the incidence of tensions and conflict. For a full description of indicators selected and related thresholds, please refer to the Methodology.

84 According to RARTs from the central and southern governorates.

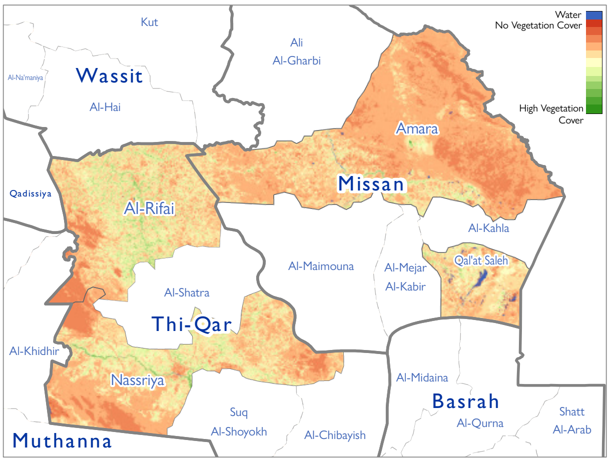
85 In northern Basra, tensions over water have spurred decades-long tribal disputes, causing death and injuries to dozens of people. An estimated 10 per cent of current tribal disputes stem from water scarcity. Nussaibah Younis, Early warning: How Iraq can adapt to climate change, *European Council on Foreign Relations* (Berlin, 2022).

## CHANGES IN VEGETATION HEALTH IN HOTSPOT LOCATIONS

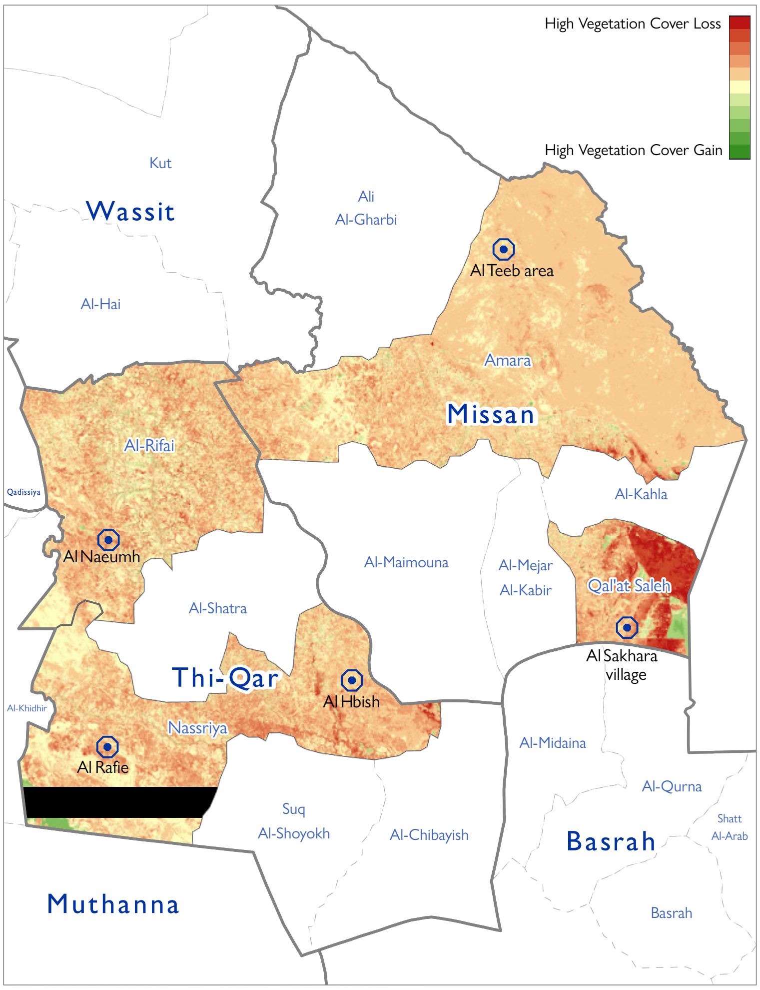
Map 6. 2014 Normalized Difference Vegetation Index (NDVI) in districts reporting high rates of depopulation




Map 7. 2022 NDVI in districts reporting high rates of depopulation




Map 8. 2014–2022 NDVI anomaly data for locations reporting highest rates of depopulation




To better understand the relationship between physical changes in the environment and climate-induced displacement, this section compares DTM displacement figures with data on vegetation health, as measured through the Normalized Difference Vegetation Index (NDVI) (Map 6, Map 7, Map 8).

NDVI is a measure of the 'greenness' of vegetation[86] that can be used to understand the density of vegetation cover as well as the health of vegetation.[87] Changes in vegetation health over time can be detected using NDVI anomaly data. This indicator compares the average NDVI in a given month to the long-term average for the same month.[88]

NDVI anomaly data were extracted from the United States Geological Survey/NASA Landsat remote sensing data and analysed in partnership with WFP's Vulnerability and Analysis Mapping team.

The maps above present the NDVI from August 2014 to August 2022 and the NDVI anomaly in August 2022 compared to August 2014–August 2021. The year 2014 is the oldest on record for Landsat-8. August was selected as the month for comparison to coincide with the data collection period (August–October 2022).

The NDVI anomaly analysis focuses on five hotspot locations with the highest rates of climate-induced depopulation.[89] The hotspot locations all fall within Thi-Qar and Missan governorates, near the end of the Euphrates and Tigris rivers, respectively. In addition to receiving reduced flows due to damming and river diversions in neighbouring countries, these downstream governorates are affected by the water management, consumption and treatment practices of governorates located further upstream.

Despite having high levels of climate-induced depopulation, these locations had varying levels of vegetation loss. This suggests climate-induced depopulation has both environmental and economic dimensions. Data on changes in vegetation health must be contextualized using relevant socioeconomic information, such as reliance on climate-sensitive livelihoods, access to basic services, food insecurity and adoption of mitigation measures. Integrating environmental and socioeconomic data will improve understanding of the consequences of climate change and environmental degradation for communities and thus the precise drivers of climate-induced displacement.

86 Landsat Missions, 'Landsat Normalized Difference Vegetation Index,' *United States Geological Survey* (Reston, n.d.).
87 Ibid.
88 Cindy Schmidt and Amber McCullum, *Creating and Using Normalized Difference Vegetation Index (NDVI) from Satellite Imagery*, NASA Applied Remote Sensing Training Program (ARSET) (Washington, D.C., 2016).
89 Fully abandoned locations were not selected for this analysis, given the limited assessment of these areas.

## NASSRIYA DISTRICT

Nassriya district in Thi-Qar Governorate shows moderate to significant vegetation loss throughout the district. Between 2014 and 2022, dense vegetation decreased by 69 per cent, while sparse vegetation fell by 49 per cent. On the other hand, barren land and built-up areas now comprise 99 per cent of the district. This loss is especially pronounced in the areas directly north of Suq Al-Shoyokh district and in the easternmost portion of the district. Additionally, since 2014, Nassriya experienced the largest percentage decline in water sources of the districts examined in this section (-95%). As indicated in NDVI maps of 2014 and 2022, Lake Sulaibiyat, located in the southwest of the district, has shrunk significantly.

Two locations within Nassriya district are labelled within the NDVI anomaly map: Al Rafie and Al Hbish. Nearly 9 in 10 families (89%) have left Al Rafie, while 95 per cent of the original population have been displaced from Al Hbish.

Al Rafie shows moderate to significant vegetation loss. The impact in Al Hbish appears more tempered, although significant vegetation loss can be observed to the west of the district.

## AL-RIFA'I DISTRICT

Al-Rifa'i district in Thi-Qar Governorate has experienced moderate vegetation loss throughout the district. Already in 2014, Al-Rifa'i had low levels of dense vegetation (covering 0.04% of the district) and a high portion of barren land and built-up areas (91%). Since 2014, sparse vegetation declined by 49 per cent, while water sources diminished by 36 per cent.

The vegetation loss observed in Al Naeumh, located in the south west, is consistent with the patterns across the district. Around 7 in 10 families (71%) have been displaced from Al Naeumh, compared to 61 per cent within Al-Rifa'i district overall.

## QAL'AT SALEH

Qal'at Saleh district in Missan Governorate has experienced dramatic vegetation loss since 2014. Sparse vegetation cover fell from 36 per cent (414 $km^2$) to 2 per cent of the district area (19 $km^2$) between 2014 and 2022. Additionally, in 2022, Qal'at Saleh had no dense vegetation remaining (0.00% of the district). Vegetation loss is particularly significant in the eastern half of the district, corresponding to the Hawizeh Marshes. In parallel, the portion of barren land and built-up areas has jumped from 57 per cent (653 $km^2$) to 95 per cent of the district area (1,094 $km^2$). Water sources have also shrunk to half their size between 2014 and 2022. Jaraiyah Lake, visible on the NDVI maps in the southeastern corner of the district, has also shrunk dramatically over this period.

Water scarcity in the district appears to be driven by damming and reduced river flows. Located on the border with the Islamic Republic of Iran, Qal'at Saleh and its marshes have been impacted by the buildup of earthern dams in the neighbouring country. Additionally, reduced flows from the Tigris River have caused water levels in tributaries to drop. In some cases, secondary rivers have dried up entirely. This has increased the distance to water bodies, making it more challenging for families to meet their basic water needs.

Al Sakhara Village, located in the south of the district, has experienced moderate to significant vegetation loss, particularly in its eastern half. Around three quarters of the original population (73%) have left this location.

## AMARA DISTRICT

Amara district in Missan Governorate shows lower levels of vegetation loss compared to the other districts under consideration here. This is likely related to the high levels of barren land already present in 2014 (98% of the district). Additionally, dense vegetation increased in Amara from 0 per cent (0.16 $km^2$) to 0.10 per cent (0.99 $km^2$), in contrast to other districts assessed. This increase in vegetation is likely attributable to reforestation initiatives that sought to plant thousands of trees in Amara to reduce the severity of dust storms. Moreover, as the district hosts the capital of the governorate (Amara city), it may have benefitted from increased attention from authorities and programmatic actors.

The decline in sparse vegetation is also more modest than that in other districts (-23%). Some vegetation loss is visible in the northern and eastern regions of the district, although more significant loss can be detected in the western half of the district and directly north of Al-Kahla district.

Al Teeb, located in the north of the district, has experienced some vegetation loss, although less than observed in other locations. This is a likely a reflection of the limited vegetation cover observed in this area in 2014. Nearly 8 in 10 families originally residing in the location have been displaced (78%).

## TAKEAWAYS

The NDVI anomaly data indicates moderate to high vegetation loss. Qal'at Saleh in particular has suffered significant vegetation loss in its marshes. Additionally, water bodies in Qal'at Saleh and Nassriya have visibly shrunk between 2014 and 2022.

However, the locations with the highest rates of depopulation were not necessarily those that experienced the highest degree of vegetation loss. This suggests that changes in vegetation cover are contributing to displacement but are not its sole determinant. As highlighted in the Random Forest analysis, dependence on land-based livelihoods and difficulties accessing basic services influence the degree to which climate change and environmental degradation impact families and thus their vulnerability to displacement.

Smallholder farming and livestock rearing are among the top livelihoods in all five locations assessed. Additionally, fishing is a key livelihood in Al Hbish and Al Sakhara Village, while in Al Naeumh, transhumance is one of the most common livelihoods. In line with the Random Forest analysis, families in four locations struggle to meet their basic food needs and have adopted mitigation measures to overcome these challenges.

Regarding access to services, around half of families do not have enough water for drinking or domestic purposes in Al Hbish, Al Naeumh and Al Rafie. Moreover, several locations did not have a secondary school, health clinic or market within five kilometres. Despite these difficulties, families in these locations have not received any aid or assistance.

Future analysis comparing NDVI anomaly and displacement data should consider selecting districts with similar living conditions in terms of livelihoods and services. Doing so will help isolate the effect of changes in vegetation health on displacement patterns. Additionally, selecting the peak month for vegetation in the locations under assessment will help illustrate the full impact of climate change and environmental degradation on vegetation health.

This analysis highlights the importance of bringing together environmental and key informant data to understand climate-induced displacement. On the one hand, NDVI data can be used to examine the physical consequences of climate change and environmental degradation on land and water sources. On the other hand, key informant data shed light on the human consequences of these environmental changes. As climate-induced displacement reflects an interaction between environmental and societal factors, making sense of this trend requires integrating these two sets of data.

# CONCLUSION

Locations reporting climate-induced displacement are confronting multifaceted challenges related to environmental hazards, water resources, access to services, sustainable livelihoods and intercommunal tensions. Many locations are experiencing a range of negative environment hazards and conditions, from droughts and sand/dust storms to increased water salinity and soil degradation. Moreover, the supply of irrigation water appears to be shrinking in most locations, driven by reductions in the quantity and quality of water, high costs of water trucking, damming and diversions and inadequate infrastructure. Widespread difficulties accessing basic services further undermine the resilience of communities in the face of environmental changes. These factors make it increasingly difficult to practice key livelihoods in agriculture, livestock rearing and fishing, forcing significant portions to abandon these livelihoods and find alternative strategies to cope with these worsening conditions. Furthermore, some groups practising these livelihoods are experiencing tensions over natural resources, especially water and grazing land. In short, climate change and environmental degradation are contributing to a complex, interconnected web of issues in the locations assessed, making it difficult for families to remain where they are.

Based on Random Forest analysis, the presence of multiple water-related issues, especially high costs for water trucking and damming or river diversions, is the strongest predictor of climate-induced depopulation. Another key predictor is food insecurity, which underscores the difficult living conditions and economic precarity that families are facing prior to displacement. The third strongest predictor is difficulties accessing basic services, which further compromise the ability of communities to cope with environmental stressors. Dependence on climate-sensitive livelihoods like agriculture, livestock rearing and fishing is also a leading predictor of climate-induced depopulation. Negative environmental changes can result in a loss of crop production, fishing yields and livestock deaths, thereby reducing income levels and the ability to maintain these livelihoods. Finally, the adoption of mitigation measures is strongly associated with climate-induced depopulation. Reliance on mitigation measures indicates families have been negatively impacted and are taking steps to overcome these challenges. However, these efforts may not suffice in the face of significant environmental challenges and may even undermine the wellbeing of households in the medium- to long-term.

# RECOMMENDATIONS

Climate-induced displacement in central and southern Iraq is primarily driven by the country's multifaceted water crisis. Addressing these challenges will require engagement and interventions at several political levels:

- **International level:** Greater cooperation over the distribution of water resources between Iraq and neighbouring countries is needed.[90]
- **National level:** The Government of Iraq, with the support of non-governmental and intergovernmental organizations, should strengthen water management policies and develop monitoring systems related to water scarcity.
- **Governorate level:** Authorities must work to improve existing water infrastructure and acquire climate-smart infrastructure. Additionally, platforms for dialogue and mediation should be established to reduce the potential for tension and conflict over natural resources.
- **Community level:** Communities require greater support to diversify livelihoods and raise awareness of the importance of water conservation.

## AREA-BASED PROGRAMMING

Many locations are experiencing wide-ranging challenges across the domains considered. However, 10 districts have shown particularly high levels of vulnerability including:

- **Qadissiya Governorate:** Afaq and Hamza districts;
- **Missan Governorate:** Al-Maimouna, Al-Mejar Al-Kabir, Amara, Qal'at Saleh and Al-Kahla;
- **Thi-Qar Governorate:** Al-Rifa'i, Nassriya and Suq Al-Shoyokh districts.

The Government of Iraq, in partnership with inter- and non-governmental organizations, should prioritize these areas for programmatic interventions and further assessment.

## AREAS FOR FURTHER DATA COLLECTION AND RESEARCH

Further data collection and research are needed to understand the relationship between slow-onset hazards and displacement, to identify high-risk areas of origin and displacement and sources of future vulnerability and to support programmatic interventions. While this assessment collected data at the location level, more granular assessments disaggregated by sex and age could shed light on the different consequences faced by different groups. Additionally, to complete the quantitative data provided by this assessment, qualitative research should seek to understand the multitude of factors feeding into the decisions of families and individuals to leave their areas of origin. Moreover, monitoring activities should integrate the perspectives of impacted families with remote sensing and satellite data on key environmental indicators.[91] Given the potential for greater climate-induced displacement in the future, researchers and programmatic actors should further develop early warning or predictive models which could signal shifting trends in the short to long term, building on existing examples.[92] Finally, local authorities and the central government should be provided with technical assistance on data collection and analysis to build their capacity to assess, monitor and address the consequences of climate change and environmental degradation based on their data.

90 IOM, *Migration, Environment and Climate Change in Iraq* (Baghdad, 2022).
91 Ibid.
92 IOM, *Somalia – Drought Related Displacement Analysis (December 2021)* (Mogadishu, 2022).

# ANNEX

## ENVIRONMENTAL DEPOPULATION AND PREDICTIVE ANALYSIS: RANDOM FOREST MODEL

The main scope of this analysis is to identify patterns of environmental migration based on the response to environmental changes and predict depopulation rate through the selection of specific characteristics related to environmental and water issues, livelihoods and access to infrastructure and services. The unit of the analysis is the location and the analysis is based on the use of Random Forest, a classification algorithm consisting of many Decision Trees that operate as an ensemble.[93, 94, 95] Random Forest uses bagging and feature randomness when building each individual tree to create an uncorrelated forest of trees whose prediction by committee is more accurate than that of any individual tree. Compared to a single Decision Tree, Random Forest works better with multicollinearity in terms of prediction as it selects a random subset of features to grow each tree so that it is less probable that collinear terms will both be selected, alleviating the issue of multicollinearity.

## TREE-BASED METHODS

Tree-based methods are a simple and yet powerful approach to handle large and complex datasets with many features interacting in non-linear ways, identify significant 'hidden' patterns and interpret them in a single and comprehensive model. They partition the space into smaller regions, where interactions are more manageable, and then fit a simple model in each region. They can be used for both classification and prediction.[96]

The tree structure comprises a hierarchically organized set of groups called 'nodes.' At the top of the tree (the root node) sits the full dataset of cases that is recursively split into a number of 'child' nodes – each containing a subgroup of cases – interconnected by branches, until no more partitioning is possible and only the terminal nodes (the 'leaves' of the tree) are left. The criterion for partitioning (or branching) examines all possible values of all available predictive variables and selects the grouping of cases that allows the maximum homogeneity in each group with respect to the value of the dependent variable. The branches and internal nodes at the top represent the independent variables with the strongest connection with the dependent variable.[97]

Different tree types are distinguished by the manner of node partitioning. In this analysis, the Chi-Square Automatic Interaction Detection (CHAID) algorithm was applied, where CHAID denotes an automatic and iterative procedure of tree development based on Pearson's chi-square statistic and corresponding p-value. At each step, CHAID chooses the independent (predictor) variable that has the strongest interaction with the dependent variable. Categories of each predictor are merged if they are not significantly different with respect to the dependent variable.[98]

## THE RANDOM FOREST MODEL: CHARACTERISTICS AND PERFORMANCE

Two different Random Forest models were developed and tested, the only difference being the definition of the dependent variable, 'environmental depopulation rate'. In the first model, the variable ranges from 'low depopulation' (0–10%) to 'medium depopulation' (11–30%) and 'high depopulation' (31–100%). In the second model, it ranges from 'low depopulation' (0–10%) to 'medium depopulation' (11–40%) and 'high depopulation' (41–100%). Both models employ the same 28 independent variables, which are listed in Table 1. All independent variables were defined as ordinal variables or binary categorical variables.

As discussed in greater detail later in this section, only Model 1 was included in the main report due to its higher accuracy on the test dataset and for the sake of simplicity.

Table 1. Variables used for the analysis

| VARIABLE | | | STRUCTURE | |
|---|---|---|---|---|
| Name | Symbol | Values (modalities) | Cases | Percentage |
| Environmental issues | $X_1$ | Low = 0–2 issues | 1 | 1% |
| | | Medium = 3–5 issues | 69 | 27% |
| | | High = 6–8 issues | 182 | 72% |
| Water issues | $X_2$ | Low = 0–2 issues | 2 | 1% |
| | | Medium = 3–5 issues | 167 | 66% |
| | | High = 6–8 issues | 83 | 33% |
| Access to services and infrastructure | $X_3$ | Low = 0–2 issues | 31 | 12% |
| | | Medium = 3–5 issues | 158 | 63% |
| | | High = 6–8 issues | 63 | 25% |
| Livelihood issues | $X_4$ | Low = 0–2 issues | 2 | 1% |
| | | Medium = 3–5 issues | 55 | 22% |
| | | High = 6–8 issues | 195 | 77% |

93 Leo Breiman, Random forests, *Machine Learning*, 45:5–32 (October 2001).
94 Tin Kam Ho, Random decision forests, Proceedings of the Third International Conference on Document Analysis and Recognition, Institute of Electrical and Electronics Engineers, Montreal, Quebec, Canada, 14–16 August 1995.
95 Tin Kam Ho, The random subspace method for constructing decision forests, *Institute of Electrical and Electronics Engineers Transactions on Pattern Analysis and Machine Intelligence*, 20(8): 832–844 (August 1998).
96 Trevor Hastie, Robert Tibshirani & Jerome Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction (Second Edition)*, Springer (Stanford California, 2001).
97 Leo Breiman, *Classification and Regression Trees.* First Edition. Routledge (New York, 2017).
98 International Business Machines Corporation (IBM), *IBM SPSS Decision Trees 21* (2012).

| VARIABLE | | | STRUCTURE | |
|---|---|---|---|---|
| Name | Symbol | Values (modalities) | Cases | Percentage |
| Tension issues | $X_5$ | Low = 0–2 issues | 228 | 90% |
| | | Medium = 3–4 issues | 9 | 4% |
| | | High = 5–6 issues | 15 | 6% |
| Recent displacement | $X_6$ | < 60% of HHs left in 2021–2022 | 119 | 47% |
| | | 60% or > HHs left in 2021–2022 | 133 | 53% |
| Damming/river diversion | $X_7$ | Present | 125 | 50% |
| | | Not present | 127 | 50% |
| Broken/inefficient water infrastructure | $X_8$ | Present | 91 | 36% |
| | | Not present | 161 | 64% |
| Reduced water allocation | $X_9$ | Present | 152 | 60% |
| | | Not present | 100 | 40% |
| Cost of water trucking | $X_{10}$ | Present | 126 | 50% |
| | | Not present | 126 | 50% |
| Small-holder farming | $X_{11}$ | Present | 208 | 82% |
| | | Not present | 44 | 18% |
| Livestock rearing | $X_{12}$ | Present | 198 | 79% |
| | | Not present | 54 | 21% |
| Transhumance | $X_{13}$ | Present | 52 | 21% |
| | | Not present | 200 | 79% |
| Reliance on land | $X_{14}$ | No activities | 33 | 13% |
| | | 1-2 activities | 166 | 66% |
| | | 3-4 activities | 53 | 21% |
| Abandoned fishing activities | $X_{15}$ | Half or more HHs | 179 | 71% |
| | | Less than half HHs | 73 | 29% |
| Reliance on bore hole/wells | $X_{16}$ | Present | 126 | 50% |
| | | Not present | 126 | 50% |
| Reliance on water trucking/ tanker (government supply) | $X_{17}$ | Present | 70 | 28% |
| | | Not present | 182 | 72% |
| Biodiversity loss | $X_{18}$ | Present | 170 | 67% |
| | | Not present | 82 | 33% |
| Soil degradation | $X_{19}$ | Present | 219 | 87% |
| | | Not present | 33 | 13% |
| Increased temperature | $X_{20}$ | Present | 201 | 80% |
| | | Not present | 51 | 20% |
| Water sufficiency | $X_{21}$ | Less than 76% of HHs | 159 | 63% |
| | | 76% of HHs or more | 93 | 37% |
| Reduced meal size as mitigation measure | $X_{22}$ | Present | 35 | 14% |
| | | Not present | 217 | 86% |
| Spent savings as mitigation measure | $X_{23}$ | Present | 18 | 7% |
| | | Not present | 234 | 93% |
| Borrowed money as mitigation measure | $X_{24}$ | Present | 53 | 21% |
| | | Not present | 199 | 79% |
| Changed agricultural activities as mitigation measure | $X_{25}$ | Present | 44 | 17% |
| | | Not present | 208 | 83% |
| Families in need of food | $X_{26}$ | None | 15 | 6% |
| | | Some = 1–24% | 63 | 26% |
| | | Less than half = 25–49% | 46 | 18% |
| | | More than half = 50–75% | 65 | 26% |
| | | Most or all = 76–100% | 63 | 25% |
| Unmet food need | $X_{27}$ | Half or more HHs | 128 | 51% |
| | | Less than half HHs | 124 | 49% |

| VARIABLE | | | STRUCTURE | |
|---|---|---|---|---|
| Name | Symbol | Values (modalities) | Cases | Percentage |
| Mitigation measures | $X_{28}$ | Low = 0–2 mitigation measures | 84 | 33% |
| | | Medium = 3–5 mitigation measures | 115 | 46% |
| | | High = 6-8 mitigation measures | 53 | 21% |
| Depopulation rate – Model 1 | $Y_1$ | Low = 0–10% | 104 | 41% |
| | | Medium = 11–30% | 88 | 35% |
| | | High = 31–100% | 60 | 24% |
| Depopulation rate – Model 2 | $Y_2$ | Low= 0–10% | 104 | 41% |
| | | Medium= 11–40% | 108 | 43% |
| | | High= 41–100% | 40 | 16% |

Table 2 and Table 3 display information about the performance of the models in terms of their accuracy (that is, the proportion of correctly classified data using the designed model) and predictive power. According to the classification matrix, the overall accuracy of Model 1 is 91 per cent if all locations are used and 61 per cent if the model is properly split into a training (80% of locations) and a test set (20% of location) to deal with overestimation. Model 2 has an overall accuracy of 92 per cent if all locations are used; however, accuracy drops to 47 per cent when the model is split into a training and a test set to deal with overestimation.

Table 2. Confusion Matrix

| MODEL 1 | | | | | | |
|---|---|---|---|---|---|---|
| Observed | Model 1 (all locations) | | | Model 1 (train and test) | | |
| | 0–10% | 11–30% | 31–100% | 0–10% | 11–30% | 31–100% |
| 0–10% | 104 | 12 | 5 | 12 | 4 | 2 |
| 11–30% | 0 | 75 | 4 | 7 | 10 | 2 |
| 31–100% | 0 | 1 | 51 | 1 | 3 | 8 |
| MODEL 2 | | | | | | |
| Observed | Model 2 (all locations) | | | Model 2 (train and test) | | |
| | 0–10% | 11–30% | 31–100% | 0–10% | 11–30% | 31–100% |
| 0–10% | 103 | 12 | 4 | 12 | 10 | 2 |
| 11–30% | 1 | 94 | 1 | 8 | 9 | 4 |
| 31–100% | 0 | 2 | 35 | 0 | 2 | 2 |

Table 3. Classification Statistics

| MODEL 1 | | | | | | |
|---|---|---|---|---|---|---|
| | Model 1 (all locations) | | | Model 1 (train and test) | | |
| Accuracy | 0.9127 | | | 0.6122 | | |
| 95% Confidence Interval | (0.8708, 0.9445) | | | (0.4624, 0.748) | | |
| No Information Rate (NIR) | 0.4127 | | | 0.4082 | | |
| P-Value [Accuracy > NIR] | < 2.2e-16 | | | 0.003128 | | |
| Kappa | 0.8643 | | | 0.4085 | | |
| McNemar's Test P-Value | 0.0003007 | | | 0.716938 | | |
| | Class 1 | Class 2 | Class 3 | Class 1 | Class 2 | Class 3 |
| Sensitivity | 1 | 0.8523 | 0.85 | 0.6 | 0.5882 | 0.6667 |
| Specificity | 0.8851 | 0.9756 | 0.9948 | 0.7931 | 0.7188 | 0.8919 |
| Positive Predictive Value | 0.8595 | 0.9494 | 0.9808 | 0.6667 | 0.5263 | 0.6667 |
| Negative Predictive Value | 1 | 0.9249 | 0.955 | 0.7419 | 0.7667 | 0.8919 |
| Prevalence | 0.4127 | 0.3492 | 0.2381 | 0.4082 | 0.3469 | 0.2449 |
| Detection Rate | 0.4127 | 0.2976 | 0.2024 | 0.2449 | 0.2041 | 0.1633 |
| Detection Prevalence | 0.4802 | 0.3135 | 0.2063 | 0.3673 | 0.3878 | 0.2449 |
| Balanced Accuracy | 0.9426 | 0.9139 | 0.9224 | 0.6966 | 0.6535 | 0.7793 |

| MODEL 2 | | | | | | |
|---|---|---|---|---|---|---|
| | Model 2 (all locations) | | | Model 2 (train and test) | | |
| Accuracy | 0.9206 | | | 0.4694 | | |
| 95% Confidence interval | (0.8801, 0.9508) | | | (0.3253, 0.6173) | | |
| NIR | 0.4286 | | | 0.4286 | | |
| P-Value [Accuracy > NIR] | < 2.2e-16 | | | 0.3307 | | |
| Kappa | 0.8717 | | | 0.1202 | | |
| McNemar's Test P-Value | 0.003437 | | | 0.4091 | | |
| | Class 1 | Class 2 | Class 3 | Class 1 | Class 2 | Class 3 |
| Sensitivity | 0.9904 | 0.8704 | 0.875 | 0.6 | 0.4286 | 0.25 |
| Specificity | 0.8919 | 0.9861 | 0.9906 | 0.5862 | 0.5714 | 0.95122 |
| Positive Predictive Value | 0.8655 | 0.9792 | 0.9459 | 0.5 | 0.4286 | 0.5 |
| Negative Predictive Value | 0.9925 | 0.9103 | 0.9767 | 0.68 | 0.5714 | 0.86667 |
| Prevalence | 0.4127 | 0.4286 | 0.1587 | 0.4082 | 0.4286 | 0.16327 |
| Detection Rate | 0.4087 | 0.373 | 0.1389 | 0.2449 | 0.1837 | 0.04082 |
| Detection Prevalence | 0.4722 | 0.381 | 0.1468 | 0.4898 | 0.4286 | 0.08163 |
| Balanced Accuracy | 0.9411 | 0.9282 | 0.9328 | 0.5931 | 0.5 | 0.60061 |

## RANKING OF FACTORS[99]

Location-level data were used to investigate the relative importance of each domain for environmental depopulation and identify the independent variables most associated with it. The ranking of factors, according to the mean decrease in the Gini coefficient,[100] is depicted in Figure 1. Despite a slight difference in ranking, both models selected the same variables as the top five factors.

**The presence of multiple water issues** is the single most important factor in Model 1 and in fifth position for Model 2. **Food needs** – that is 'half or more households or more are in need of food' – is the second most important factor in both models, whereas **difficult access to services** is the third most important factor in the Model 1 and the most important in Model 2. **This may point in the direction of particularly remote rural locations**, where access to secondary education, health and markets may be more problematic. **Reliance on land** (fourth most important factor in Model 1 and third in Model 2) and **mitigation measures** – that is, the number of mitigation measures that families adopt at the location – are respectively the fourth and fifth most important factors in Model 1 and third and fourth in Model 2.

Singularly, **the cost of water trucking and damming or river diversions appear to be of high relevance.**[101]

Other important risk factors are **reliance on bore holes/wells, transhumance** and **fishing activities**. Model 2 also outlines how **environmental displacement that started earlier than 2021** and **bio-diversity loss may be other red flags that may signal a path towards increasing depopulation**. Tension issues – that is, a combined indicator taking into account tensions between groups, tension over natural resources and whether there has been an increase in tension – ranked within the first ten factors in both models. As a result, this indicator acquires a relative importance.

99 Even though collinearity is mostly dealt with when it comes to predictive power, more caution is demanded when dealing with the scoring of factors. If two or more variables are correlated, once one of the two is selected for splitting a node in a Tree, it is highly likely that the other variable will not be selected for further splitting since its effect has already been taken into account by the selected variable. As a result, it does not provide further explanation of the output variation. Hence, the overall importance of the two (or more) correlated variables in the Random Forest will be reduced.

100 The mean decrease in Gini coefficient is a measure of how each variable contributes to the homogeneity of the nodes and leaves in the resulting Random Forest. The higher the value of mean decrease accuracy or mean decrease Gini score, the higher the importance of the variable in the model.

101 As noted in the Tree Model, this is often the case because a reduction in irrigation sources, a decrease in rainfall or in water quality were observed in nearly all locations, making these factors unfit for classification purposes despite being the most significant risk factors.

Figure 1. Ranking of factors based on mean decrease in Gini coefficient

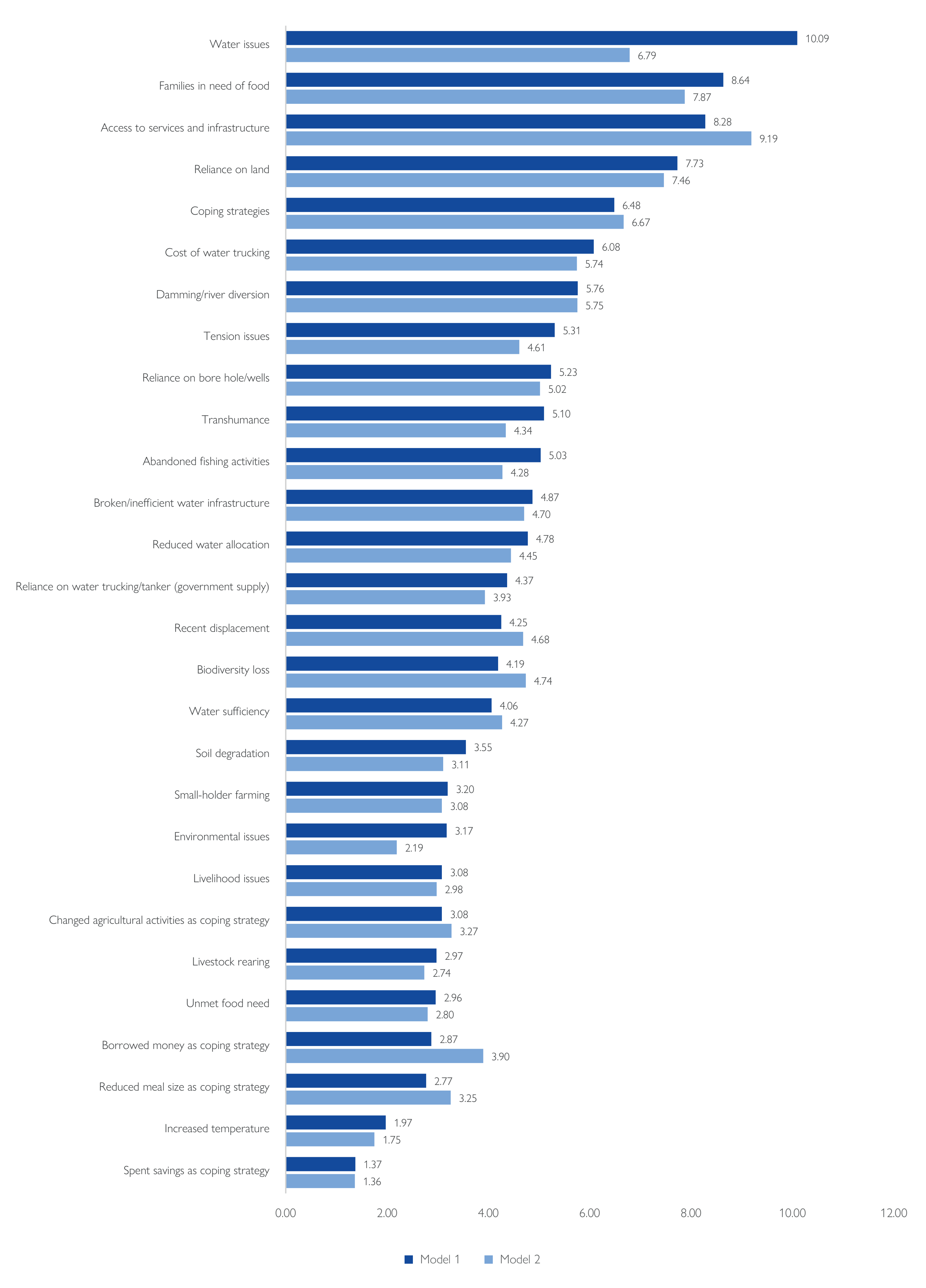


Table 4. Ranking of factors

| PREDICTORS | MODEL 1 | MODEL 2 |
|---|---|---|
| Water issues | 10.093595 | 6.788625 |
| Families in need of food | 8.635013 | 7.873919 |
| Access to services and infrastructure | 8.280772 | 9.187541 |
| Reliance on land | 7.729013 | 7.461919 |
| Mitigation measures | 6.482925 | 6.66863 |
| Cost of water trucking | 6.079559 | 5.744366 |
| Damming/river diversion | 5.763959 | 5.754345 |
| Tension issues | 5.306974 | 4.609381 |
| Reliance on bore hole/wells | 5.234257 | 5.016876 |
| Transhumance | 5.097684 | 4.34187 |
| Abandoned fishing activities | 5.029385 | 4.277717 |
| Broken/inefficient water infrastructure | 4.870359 | 4.7037 |
| Reduced water allocation | 4.77612 | 4.44546 |
| Reliance on water trucking/tanker (government supply) | 4.367511 | 3.929374 |
| Recent displacement | 4.251637 | 4.683404 |
| Biodiversity loss | 4.189264 | 4.736337 |
| Water sufficiency | 4.063657 | 4.269101 |
| Soil degradation | 3.553309 | 3.107334 |
| Small-holder farming | 3.196347 | 3.081293 |
| Environmental issues | 3.174667 | 2.191187 |
| Livelihood issues | 3.081334 | 2.976742 |
| Changed agricultural activities as mitigation measure | 3.080598 | 3.271313 |
| Livestock rearing | 2.974343 | 2.735444 |
| Unmet food need | 2.958935 | 2.799299 |
| Borrowed money as mitigation measure | 2.873577 | 3.896902 |
| Reduced meal size as mitigation measure | 2.76915 | 3.25481 |
| Increased temperature | 1.973129 | 1.750646 |
| Spent savings as mitigation measure | 1.372394 | 1.3639 |

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