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Digital Market Intelligence and Agricultural Resilience in the Kurdistan Region of Iraq: Establishing Food System Authority via Data-Driven Governance

Didar Rahim & Vaclav Trojan

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Digital Market Intelligence and Agricultural Resilience in the Kurdistan Region of Iraq: Establishing Food System Authority via Data-Driven Governance

By Rahim Didar[*] & Vaclav Trojan[±]

In the agriculture sector in the Kurdistan Region there is a big change going on. Our region has fertile soil and excellent market opportunities, but the impact of climate change, market instability, and institutional fragmentation has undermined the sector. This situation leads to food shortages and financial instability because of reliance on quick imports and lower private sector investment. In addition, governance shortcomings and disconnects in the information chain have hindered the reform and success of the digital projects. This policy paper presents an innovative approach to enhance economic resilience and stability through the "National Digital Market Intelligence Architecture" (DMIA), supported by the "Digital Agricultural Authority" (DAA). The study examines climate change trends, production and trade statistics, financial risks, and global comparisons in detail to build a sovereign, integrated, and efficient agricultural intelligence framework. The proposed DMIA system seeks to integrate different data sources and forecast production and imports using sophisticated analysis, as well as provide quick insights on market conditions and weather to decision makers, farmers, and investors. The implementation of this five-year plan requires a legal framework, data systems, capacity building, financial strategy, and risk management. The move is expected to reduce the price of emergency food imports by 20%, increase smallholder farmers' incomes by 30% and invest $20 to $25 million in the agriculture sector, improving food security and how it is governed in the region. The "Vision Institute for Strategic Studies" plays a key role in assessment, future planning, and capacity building, with an emphasis on transparency, data reliance, and compliance with international standards. Using advanced digital tools in institutions will help the KRG shift from just reacting to crises to managing agriculture in a more efficient and inclusive way that attracts investors, which will strengthen local stability and food security in our region.

Keywords: *digital agriculture, market intelligence, food security, climate resilience, agricultural governance, Kurdistan Region of Iraq*

[*]Director of Studies, Vision Foundation for Strategic Studies, Iraq.
[±]Assistant Professor, Iraq.

Introduction

The agricultural sector in Kurdistan Region of Iraq (KRI) is at a pivotal moment (World Bank, 2021; FAO, 2022). Formerly the bedrock of rural livelihood (i.e., subsistence economic viability and symbol of self-reliance), it now faces structural weakness as a product of climate variability, resource mismanagement and fragile institutional coordination (UNESCWA, 2020; World Bank, 2021). On a global scale, it has increased its dependency on food imports over the past decade with Food and Agriculture Organization (Food and Agriculture Organization of the United Nations (FAO, 2024)) stating nearly 80% of all the cereals and fresh produce used in KRI are imported from neighboring markets. Such dependence challenges the socio-economic viability of the Kurdistan Regional Government (KRG), and exposes the region to external shocks, such as that experienced in the 2022–23 global grain crisis, which caused import prices to increase by >40% (World Bank, 2023; IMF, 2023). Although KRI has substantial agricultural potential, its plains are fertile, its microclimates vary greatly, and it has a young labor force (FAO, 2021; International Food Policy Research Institute (IFPRI, 2020)), the food system in KRI remains stuck in a reactive situation. Policies are generally implemented with little to do with proactive intelligence or pressures on the environment, and are instead influenced largely by emerging market shocks (OECD, 2019; World Bank, 2022). This problem is further magnified by the fragmentation of meteorological, agricultural and trade data: when data from sectors is shared between ministries and donor programs these are rarely combined and analysed in a meaningful manner, which contributes to the problem (FAO, 2022; UNDP, 2021). Poor information leads to bad procurement, bad forecasting and not much private investment (World Bank, 2022; International Fund for Agricultural Development (IFAD, 2021).

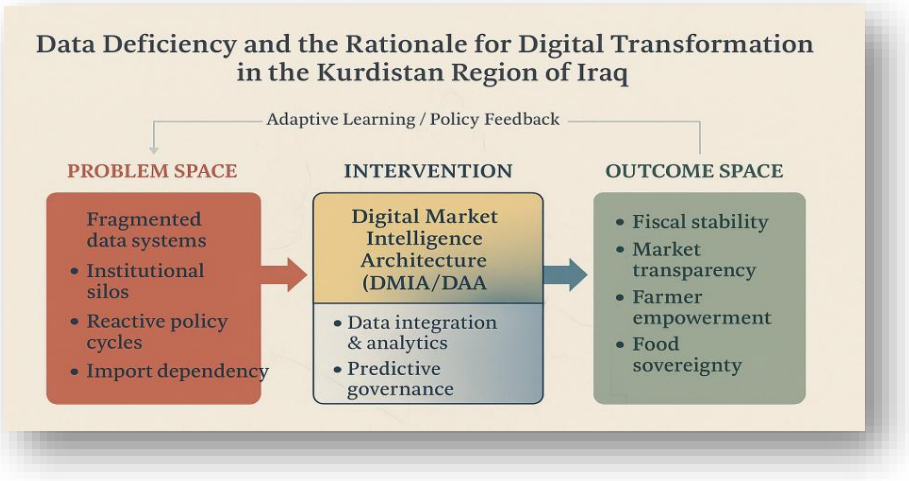
The incorporation of both digital agriculture and data-driven governance is required to improve food systems worldwide (World Bank, 2019; FAO, 2020). For instance, India with the National Agriculture Market (e-NAM), and Ethiopia with the Agricultural Transformation Agency (ATA), display the potential of integrated digital infrastructures to turn fragmented agricultural terrains into living, data-rich ecosystems which provide a wealth of information flow through to the right type of resources (Government of India, 2021; ATA, 2020; World Bank, 2020). These systems improve market transparency, yield forecasting, and climate-risk management through timely data (OECD, 2021; FAO, 2020) thereby strengthening economic and social outcomes. The KRI mechanism is digitally underdeveloped and highlights the poor coordination between statistical services, research institutions and decision makers (World Bank, 2021; UNDP, 2022). Climate change is further worsening these vulnerabilities.

The United Nations Development Program (UNDP, 2023) stated that if the situation continues in this direction until 2050, Iraq's temperature will rise by 1.5 to 2.5 degrees Celsius in general and rainfall will decrease by 9%. These are not just numbers but a direct threat to demi wheat fields in the Erbil, Sulaimaniyah, and Duhok provinces, which account for 70% of our fertile land

(FAO, 2022; ICARDA, 2021). When the soil dries up and the rain does not fall as the farmer expects, the lives of our villagers are in danger.

A closed circle is created here; Due to low GDP, the government is forced to allocate large budgets for emergency imports and food subsidies (World Bank, 2023; IFAD, 2022), putting heavy pressure on the regional budget. Today we face two major threats: the economic deficit and the threat to food security. If we do not prepare for these changes early and strategically, the crisis will deepen further and have negative effects on every individual in the region (UNDP, 2023; FAO, 2024).

Figure 1. *Conceptual Framework of the Agricultural Resilience Problem and Proposed Policy Response*



KRI Agricultural Governance: Policy Gap

This study focuses on two crucial questions: First, how can an "integrated digital market information mapping" strengthen resilience, increase efficiency and guarantee equity in the Kurdistan Regional Government's agricultural sector? Second, what administrative and financial arrangements are needed to establish and sustain this system in the political and economic reality of a semi-independent region?

To answer these questions, the study conducted a political and institutional comparison process; it combines the data of the stakeholders of this sector and the ministries of the Kurdistan Regional Government. Scientifically, it relies on the theories of "adaptive governance" and "socio-technical change" to show a reform path that is compatible with the political reality of the region on the one hand and has significant economic value on the other.

Within these theories, digital market knowledge is not only a technological tool but also the main driver of change. The study offers a set of practical recommendations and a clear implementation roadmap, which relies on strategic collaboration and integration of different capabilities. Our main goal here is not just to propose a few digital tools but to devise a management framework that

transforms agricultural data into a «public asset». This wealth will make farmers and the agricultural sector more resilient to crises and ultimately strengthen the sovereignty of the food system in the Kurdistan Region.

Analytical and Theoretical Framework

The envisaged agricultural transformation for the Kurdistan Region of Iraq (KRI) transcends a mere technical endeavor in digitization. It is a governance innovation based on how governments and semi-autonomous regions develop resilience in the face of uneven formal institutional capabilities. This section outlines the essential concepts utilised in the development of the Digital Market Intelligence Architecture (DMIA) and the Digital Agriculture Authority (DAA). The analysis draws upon three interrelated domains of inquiry: adaptive governance, socio-technical systems and digital public goods, as well as the political economy of reform.

Adaptive Governance and Anticipatory Capacity

Adaptive governance implies how institutions may learn, self-organize and adapt to challenging socio-ecological systems (Chaffin, Gosnell & Cosens, 2016). Adaptive governance in agriculture involves early warning systems, scenario planning, and policy modifications. Holling (1978) and Folke et al. (2010). The infrastructure, resources, informational feedback, and reaction capacity are major determinants of resilience. As the relevance of the phenomenon of climate variability and market shocks within KRI continues to increase, adaptive governance emerges as an important concept from the perspective of governance theory.

Today, the poor handling of fragmented data streams and disconnected decision making results in an inefficient model: delayed feedback and reactive crisis response. It is the DMIA framework that proposes to address this and strengthen anticipatory governance. The KRI can move from reactive import strategies to proactive risk management and strategic investment by centralizing and analyzing all production, climate, and market data.

Socio-Technical Transitions and Digital Public Goods

The transformation of agriculture into a digitally controlled system involves tech integration along with the simultaneous change of social and technological practices. Socio-technical transition theory argues that meaningful change does not happen without both shifting technology, changing institutional paradigms, and reshaping user practices (Geels, 2002). Digital agricultural applications mainly depend on public digital records, accessible and extensible data platforms, geospatial infrastructure, and price monitoring portals, consequently serving as an essential accelerator for commercial entrepreneurship. International evidence further supports this argument. The e-NAM platform in India serves as a national public asset that drives private logistics and fintech

innovations. At the same time, Ethiopia's ATA has developed farmer registries and price dashboards that lenders and aggregators can use as a basis for services. The DMIA is designed to become a digital public asset which is fair, open and objective, accountable to its stakeholders and governed by existing benchmarks which encourages innovation. The custodian will be the Digital Agriculture Authority defining regulations on access, interoperability, and data privacy.

Political Economy of Reform in Semi-Autonomous Regions

In fragile and hybrid governance settings technological solutions often fail for several reasons, most notably due to entrenched interests and fragmented authority (North, Wallis & Weingast, 2018). On the KRI side, there is fragmented agricultural data across ministries, the establishment of parallel reporting systems, which are driven by donor-funded programs, and effects of market power accrued by intermediaries.

The political-economic analysis of the situation suggests two complementary strategies for resolution. The first is to build a strong coalition so that the initial reforms have tangible results; that means farmer associations should have easier access to price indicators, ministries should improve their planning capacity, and investors should have access to accurate and reliable risk information. Second, the transparency process should be developed in a phased and gradual manner. Implementing some practical steps and demonstrating the benefits, before requiring extensive information exchange, is the best way to build trust between institutions and market actors.

Within this perspective, the establishment of a semi-autonomous "Agricultural Development Authority" (DAA) could be seen as a central approach. This model remains between two incorrect poles: the first is the direct intervention of the ministries, which threatens to politicize the process, and the second is the platforms that are run only with external assistance and lead to further disruption and fragmentation of work.

Therefore, it is proposed to create a legal and accountable institution. The finances of this institution should be a mixture of general government funding, clear service revenues, and time-bound external financial support. In our opinion, this style of management is not only more sustainable but also serves as a strong foundation for the institution to remain trusted among the market and farmers over time.

Synthesis: Why DMIA + DAA are the Right Fit

The combined application of these three perspectives yields the logic that informs KRI:

1. From adaptive governance we obtain the normative imperative: the region must anticipate shocks, not merely respond.
2. Socio-technical transition theory helps us structure a digital ecosystem which catalyzes market modernization rather than isolated tools.

3. Analysis of political economy provides a basis for the design that is implementable in a contested and fragmented environment. Accordingly, the DMIA and DAA are not merely technical "IT systems," but in effect policy architectures, and an institutional and digital spine for agricultural modernization. With this plan, they seek to produce high-quality data as a public good; to stimulate investment and innovation; and to make the food system resilient to climate and market volatility.

Methodology and Data

Research Design

Using the comparative institutional and systems analysis approach, this study investigates a digitally enabled market intelligence system and its promising role in improving the agricultural resilience of the Kurdistan Region of Iraq (KRI). This design fits well, since the research question encompasses not only technical feasibility but also governance, institutional incentives, and reform in contexts of fragility.

The qualitative synthesis was operationalized through a structured evidence matrix. Evidence was classified under four analytical dimensions: climate and production risk; market and trade exposure; institutional capacity and coordination; and digital-governance readiness. Findings from statistical datasets, government reports, and international institutional sources were triangulated across these dimensions. Where sources differed in coverage, timing, or definition, the inconsistency was recorded as a limitation rather than resolved through unsupported assumptions. The resulting synthesis was then used to connect diagnosed vulnerabilities to specific design requirements for the DMIA and DAA.

The screening process consisted of three stages:

Climate risk, reliance on imports, market opacity, and institutional fragmentation constitute structural vulnerabilities.
Comparative benchmarking analyses digital agricultural systems in Ethiopia, India, and Morocco – all experienced similar difficulties in unstable or transitional settings.
Development of Policy Architecture, integrating findings into a context-specific framework for a Digital Market Intelligence Architecture (DMIA) and a Digital Agriculture Authority (DAA), along with a practical implementation strategy.

Data Sources

<u>Sources and Principles of Analysis of this Study</u>

In order to present a true and accurate picture of the agricultural situation in the Kurdistan Region, we had to rely on a variety of reliable data from local and

international sources. These analyses are not just numbers but reflect an economic and environmental reality:

First, in terms of climate and environment, based on the reports of the United Nations Development Program (UNDP, 2023) and the scientific conclusions of the sixth report (IPCC AR6), we have tried to account for the changes that directly affect temperature and drought. These rapid and extraordinary changes have been understood through the use of the World Bank's 2024 climate portal data as a roadmap.

Secondly, for the verification of production data, we used the database (FAOSTAT, 2024) and official statistics from the Ministry of Agriculture and Water Resources of the Region (2023) as the main sources. Alongside these, the analyses published by the International Food Policy Institute (IFPRI) on market movements have helped us understand the problems our farmers face in the markets.

Third, in the economic and trade section, the comparison of WTO statistics with the budget reports of the Ministry of Finance and Economy (2020-2024) provides a clear picture of the volume of food imports and financial consequences.

Fourth, to understand how investment can maintain food security, we have resorted to the World Bank's Agricultural Monitoring and the Global Food Security Index (GFSI). These resources help us envision how the private sector can play a more effective role in the meantime.

Finally, in order not to fall victim to local perceptions and to draw on the experience of other countries, we have used three comparative examples: the experience of the Agricultural Change Agency in Ethiopia, the National Agricultural E-Market in India, and the Green Generation 2030 plan in Morocco. These three examples show how economic and environmental challenges can be met by modernising mechanisms.

Climate Baseline

Consequences of Climate Change on the Agricultural Sector in the Kurdistan Region

According to international and local statistics, the average annual temperature in northern Iraq has risen by 0.7 degrees Celsius since the 1990s. The United Nations Development Program (UNDP, 2023) and the World Bank Climate Information Portal (2024) warn that by 2050, this rise will reach between 1.5 and 2.5 degrees Celsius. On the other hand, over the past twenty years, rainfall has decreased by 9%, and the uncertainty of the rainfall pattern poses a serious threat to wheat production, which is a strategic crop and accounts for about 70% of the Kurdistan Region's agricultural sector (FAOSTAT, 2024).

Also, based on the "Palmer Drought Severity Index" (PDSI), the intervals between severe drought waves have shortened at a worrying pace; somehow it now repeats every 4 to 5 years, whereas in the 1980s, this phenomenon was recorded only once a decade.

To understand the local impacts of these changes, we have compared these climatic indicators with data on rainfall and wheat production levels obtained from the Kurdistan Regional Directorate of Agricultural Research. This

interpretation allowed us to understand more precisely the extent of the risks and their direct relevance to regional food security.

Production and Import Dependence

Domestic production of grain in KRI is not stable enough. According to FAOSTAT, drought and pest outbreaks resulted in wheat production falling from 1.15 million metric tons in 2017 to 0.78 million metric tons in 2023. For other staples, the self-sufficiency ratios still remain very low. In general it means that the local production of apples and tomatoes meets only 35–40% of the total demand at present. Cereals' dependence on imports increased from 68% in 2010 to 82% in 2023. Emergency grain imports are expected to reach USD 320 million in 2022–2023, making up approximately 5.4% of the discretionary budget (KRI Ministry of Finance, 2023).

Institutional Mapping

Documents and Stakeholder Mapping Reveal Significant Fragmentation in Data Governance

1. The process of collecting and managing agricultural and climate data in the Kurdistan Region is spread over five different institutions due to administrative divisions. This fragmentation is a strategic stumbling block that prevents data from becoming a scientific basis for decision-making, as information is trapped in isolated "silos" with limited ability to transform into valuable information.
2. There are currently no established data interoperability standards or legal requirements in place.
3. Donor-funded pilot platforms (e.g., USAID agro-market info systems) were discontinued or siloed after project cycles, producing "data islands" without a permanent institutional home.

A stakeholder influence grid indicates that powerful import intermediaries own significant influence yet exhibit minimal desire for transparency, cooperatives demonstrate moderate influence coupled with a high interest in transparency, while smallholders display limited influence but a strong interest in transparency. This study informs coalition-building and graduated transparency initiatives.

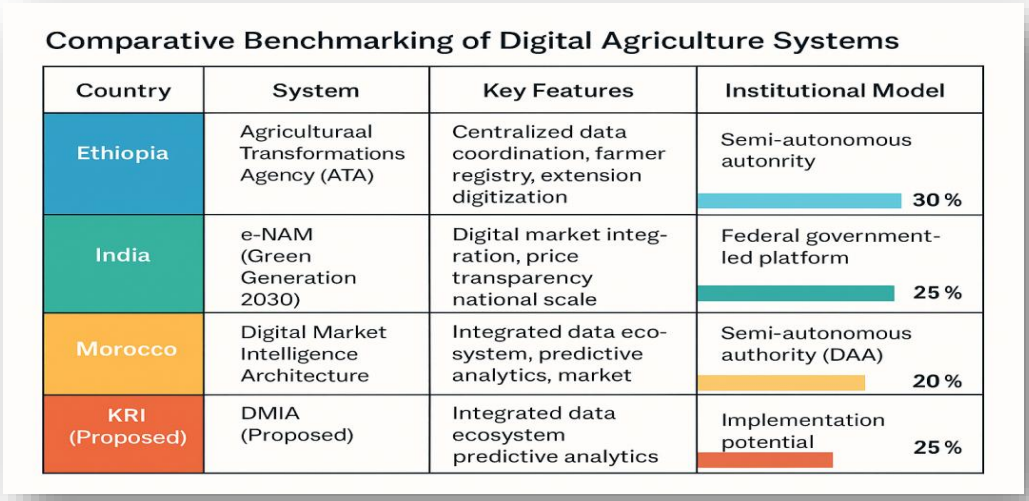
Comparative Benchmarking

The comparative cases were selected purposively rather than treated as direct institutional equivalents to the KRI. Four criteria guided selection: (1) relevance to agricultural market intelligence, digital public infrastructure, or integrated agricultural governance; (2) experience operating under institutional fragmentation, capacity constraints, or complex multi-level governance; (3) availability of documented implementation evidence; and (4) transferability of institutional and technical lessons to a subnational reform setting. Ethiopia,

India, and Morocco provide complementary benchmarks for institutional coordination, market integration, farmer-facing digital services, and climate-responsive agricultural modernization.

1. Ethiopia, Agricultural Transformation Agency (2010–present): This agency has been able to curb fertilizer shortages and, in times of drought, to react quickly and practically by using data analysis and accurate record keeping of farmers.
2. India, National Electronic Marketplace (e-NAM) (2016–Present): This is the successful example of integrating more than 1,000 major marketplaces in the country into a single digital platform. The move has not only boosted farmers' profits but also encouraged investors to come into the agriculture sector with capital and technology.
3. Morocco, Green Generation Strategy 2030 (2019–present): Morocco has formulated this plan based on detailed climate and trade data. The importance of this strategy is that it scientifically reorganizes the financial support system (SABSI) and, with a specific objective, seeks to increase the export capacity of agricultural products.

Figure 2. *Comparative Benchmarking of Data-Driven Agricultural Governance Models*



Analytical Tools

The study incorporates:

1. Gap Analysis: evaluates KRI's data value chain against established global best practices.
2. Scenario Modelling: The analysis compares a business-as-usual procurement pathway with a predictive-procurement pathway supported by DMIA intelligence. Four criteria are used to construct and compare the scenarios:

production and import dependence, climate-risk signals, indicative procurement exposure, and plausible improvements in forecast timeliness. The modelling does not claim causal prediction; because comprehensive farm-level cost and transaction data are unavailable, the resulting estimates are directional policy scenarios used to test the plausibility and fiscal significance of anticipatory decision-making.

3. Political Economy Diagnostics: borrows ideas from North et al. (2018) to assess the incentives for reform, the risks of capture or opposition.

Limitations

This study has several limitations. Local agricultural, trade, climate, and fiscal datasets are not updated consistently, and some series differ in geographic coverage, reporting frequency, or institutional definition. Comprehensive farm-level cost, income, and transaction data are unavailable, which limits the precision of cost-benefit and distributional estimates; the scenario results should therefore be interpreted as directional policy estimates rather than causal forecasts. The comparative cases are used to identify transferable design principles and are not assumed to reproduce the KRI's political economy or administrative structure. The study also relies primarily on secondary institutional and statistical evidence rather than primary interviews, surveys, or experimental data. These limitations do not remove the strategic value of the analysis; instead, they demonstrate why a coherent architecture for timely, interoperable, and auditable agricultural data is itself a central reform requirement.

Empirical Analysis: Structural Vulnerabilities of the Agri-Food System in the Kurdistan Region of Iraq

This part integrates data from the climate, market and institutions to explore why the Kurdistan Region of Iraq (KRI) is experiencing food insecurity and fiscal vulnerability despite its arable land and human resources. The assessment is organized on five interrelated topics for vulnerability: climate and ecological stress, production volatility and dependence on imports, market opacity and uneven power distributions, institutional fragmentation, and investment risk and capital flight. All these dimensions are anchored in quantifiable indicators and associated with the governance challenges that the proposed DMIA aims to resolve.

Climate and Ecological Stress

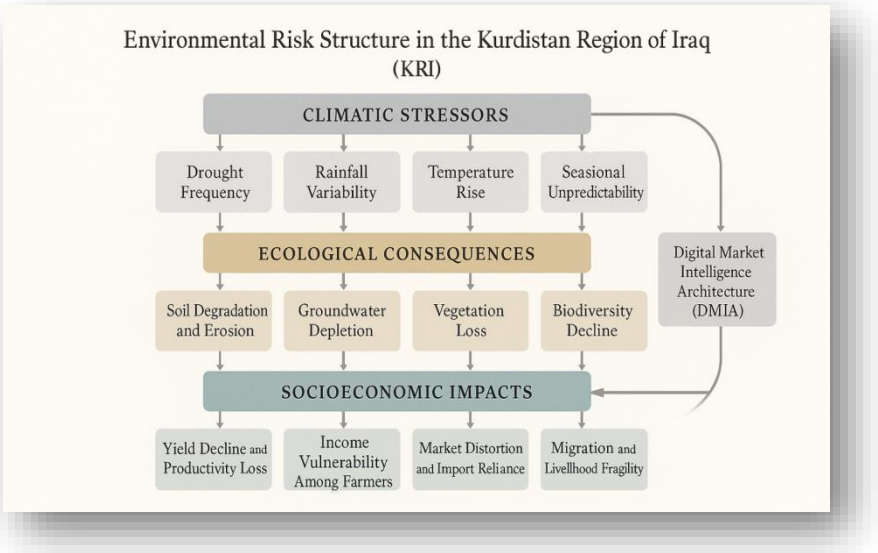
Kurdistan has always been known as the nest of wheat and blessings; The geography, sandwiched between a Mediterranean and continental climate, has relied on agricultural income for many years with its riverine soil and seasonal rains. But today, the situation has changed in such a way that even farmers feel the imbalance the weather has brought to their land. Previous generations speculated on their experience, but today science confirms that same fear; the

0.7 degree Celsius rise in temperature since the 1990s is not just a number but an unwanted heat that deprives the soil of drinking water. The "United Nations Development Programme" (UNDP, 2023) and the "Sixth IPCC Report" clearly warn that by the middle of this century, the world is heading for further warming (1.5 to 2.5 degrees Celsius), which for a region like ours means fighting water scarcity.

According to the World Bank Portal (2024), rainfall has decreased by 9% for twenty years, and worse, the rainy season has gone out of order. For a farmer who has spent his entire life on wheat maturity, this 9% reduction, according to FAO estimates (2023), means a 15% drop in yield. That is, a slight imbalance at the beginning of planting means disappointment in the harvest season. Since the 1980s, drought has become an unwelcome guest that visits us every 4 to 5 years and stubbornly takes the crops of our land.

It is not just the climate that is exhausting our land, but improper human manipulation has also complicated the situation. NASA MODIS 2000–2023 data show how overgrazing and random plowing in Erbil and Sulaymaniyah have made the soil unable to stay green and lose its fertility. But we, living in this land, have not yet developed an "integrated monitoring system" which would tell the farmer beforehand, "Your land will not tolerate this type of cultivation this year. "The harsh truth we have to face is that if we don't factor these warnings into our day-to-day planning and farming, we'll lose more land.

Figure 3. *Environmental and Climate-Risk Framework for the Kurdistan Region of Iraq*



Production Volatility and Import Dependence

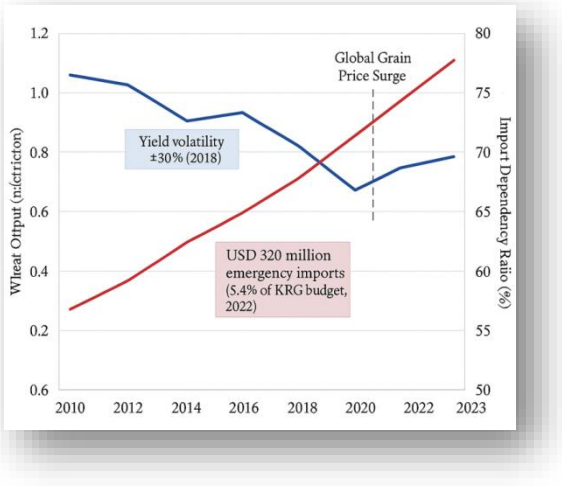
When we look at the production data, we see that the situation is more complicated than expected. For example, wheat, the backbone of our agriculture, has declined from 1.15 million tonnes to 0.78 million tonnes in six years (2017-2023). The strange thing is that our farmers have tilled as much land as before, but disease and low yields per unit of area have frustrated their hopes. The same

situation is true for crops such as tomatoes, apples and pomegranates; the 30% change in tomato yield is a sign that we have not been able to take the necessary steps in terms of irrigation technology and crop protection.

When these products are in short supply in the fields, we immediately start importing. Looking at the statistics: In 2010 we imported 68% of our grain, but the percentage is set to increase to 82% in the coming years. This situation is a heavy political and financial burden on the region, since we have to buy grain from Turkey and Iran no matter what happens. With world prices on the rise, the region will have to spend US$320 million on emergency wheat purchases in 2022 - equivalent to 5.4% of the government's budget for public expenditure.

Ultimately, this situation will impact the citizens directly. The IMF said any 20% rise in world prices would eat up 0.6 per cent of Iraq's GDP because we always appear to be "compulsory buyers" in the market. According to the Global Food Security Index (GFSI), we are performing poorly; while families in poor villages spend more than a third of their income on bread and food alone, any crisis in the market directly threatens their lives. The reality is that without careful price tracking and a long-term purchasing strategy, these shocks and crises will increasingly exhaust our people.

Figure 4. *Wheat Production and Cereal Import Dependence in the Kurdistan Region of Iraq, 2010–2023*



Source: FAOSTAT (2024); KRI Ministry of Finance (2023).

Figure 4 illustrates Iraq's Kurdistan Region's 2010–2023 wheat output and cereal import dependency.

Market Opacity and Power Asymmetries

The study of agricultural market structure highlights a deep gap and a persistent imbalance of access to information between farmers and intermediaries. This imbalance not only directly affects farmers' incomes but also leads to economic

distortions of the local market. Farmers are forced to sell their produce to traders at the cheapest price during the harvest season due to a lack of accurate and advanced information on demand and market availability, as well as a lack of advanced arsenals and refrigerators. This situation causes the real price of products to disappear from the market, and control of the price falls completely into the hands of intermediary groups.

According to data from a comprehensive 2022 survey by the International Food Policy Institute (IFPRI), more than 70% of wheat farmers in different regions reported that there is no reliable source of information or price information system to keep track of daily or weekly market prices. In this regard, comparing the situation of farmers in Sulaimani and Halabja with their counterparts in Duhok and Erbil shows that they all suffer from obstacles such as poor internet infrastructure and high transportation costs. At the same time, poor refrigeration and transportation systems cause a large proportion of crops to spoil only in the post-harvest stage; according to the Food and Agriculture Organization of the United Nations (FAO) in a 2023 report, more than 25% of agricultural production will be destroyed or significantly degraded due to lack of storage facilities.

In the absence of market transparency, farmers' associations and trade unions lose their ability to resist and negotiate. This vacuum provides a favorable environment for the emergence of illegal cartels that can virtually direct prices at will. The impact of this situation is comprehensive; On the one hand, deprived of accurate price indicators, farmers are forced to make production decisions based on "traditional" experience and past years, rather than current scientific market demand. This imbalance leads to two proven negative phenomena:

1. **Overproduction:** This phenomenon is as seen in the 2021 tomato season, when farmers produced more than necessary without knowing the market demand and were forced to throw away their products in the absence of a market.
2. **Shortage:** This situation is similar to what happened in 2022 in onion and potato production, which eventually reduced domestic supply and forced governments and traders to rely on imported products that cost the country more economically.

In short, the solution to this problem can only be achieved by creating open information systems, supporting refrigeration infrastructure, and empowering professional associations to negotiate so that the farmer can compete in a fair market.

Institutional Fragmentation and Data Gaps

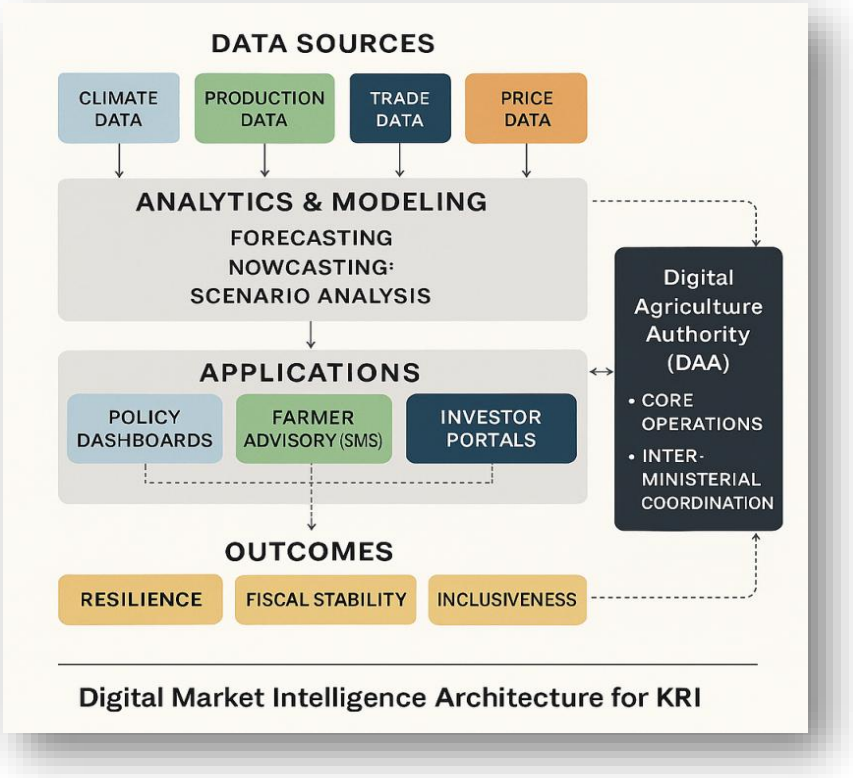
The largest overall systemic vulnerability that exists today is data fragmentation. The MoAWR collects statistics on crop acreage but the data they provide are quite inconsistent in nature and do not include remote sensing technologies. The Meteorological Department maintains climatic records; however, it rarely shares this information with other organizations. Trade flow data is available to customs

and trade directorates, but they lack real-time analytical dashboards. For instance, donors like USAID, GIZ, and FAO set up micro-portals and they operate throughout the entire project cycle before they end operations. Interoperability and data sharing are not required under a statutory mandate. As a result:

1. Yield data are often published two to three years late.
2. Weather advisories are not tied to planting or input selections.
3. Import contracts lack sound supply-demand forecasts.

Institutional competition reduces capacity: ministries guard data for influence and budget justification; provincial agencies run alternative systems. This environment erodes trust and discourages private investment in digital agriculture because no stable, authoritative platform exists.

Figure 5. *Technical Architecture of the Digital Market Intelligence Architecture (DMIA)*



Investment Risk and Capital Flight

Another fundamental problem is that investment in the region's agricultural sector is fragile. According to the World Bank (2022), less than 2% of bank loans are allocated to this sector. The reason is obvious; lenders say investment risk is high due to lack of reliable data on product levels, market analysis, and weather forecasts, so they are raising loan prices and shortening repayment periods.

Although Turkish and Gulf investors also invest sometimes, frequent changes in regulations and a lack of information models to forecast profits are cooling them off as well.

This lack of investment in infrastructure has had its consequences; for example, the capacity of "refrigerators" is now only 30% of the demand (FAO, 2023). On the other hand, companies offering digital services need a base of data to be able to provide advice or reassurance to the farmer, but the lack of that information is an obstacle. Even our irrigation system is very backward compared to neighboring countries; the lack of a public digital infrastructure makes it impossible for the private sector to manage risks scientifically. The truth of the matter is, without organized data and a digital infrastructure, the farmer and the investor both face enormous uncertainty.

Integrative Assessment

Taken together, the evidence reveals a mutually reinforcing vulnerability cycle. Climate volatility, combined with weak early-warning capacity, generates production shocks that increase the likelihood of emergency imports. Market opacity and incomplete information weaken farmers' bargaining power and facilitate price distortions. Institutional fragmentation delays fiscal responses and reduces the durability of donor-supported investments, while uncertainty over production, market, and climate risks discourages private capital and infrastructure finance. These dynamics help explain why successive agricultural-modernisation initiatives have produced limited structural transformation: without a trusted and predictive information system, public policy remains reactive and investment decisions remain constrained by uncertainty.

The proposed DMIA–DAA model addresses this cycle through four connected functions. Integrated climate and production data would support early warning and procurement planning; publication of market prices and analytical signals would improve transparency and strengthen producers and cooperatives; common data standards and legally grounded interoperability would improve coordination among ministries and development partners; and investor-facing intelligence would reduce information risk and support financing for cold chains, irrigation, processing, and agricultural inputs.

Policy Design: The Digital Market Intelligence Architecture (DMIA)

Concept and Rationale

The Digital Market Intelligence Architecture (DMIA) is designed to resolve three binding constraints.

1. Fragmented and delayed information.
2. Opaque markets and weak price discovery.
3. High fiscal exposure arising from reactive procurement.

The DMIA operationalizes anticipatory governance by converting multi-source data (production, climate, trade, and prices) into policy- and investment-grade intelligence. Crucially, it is not a donor "platform" but a sovereign state capability anchored in law and financed through a hybrid model (public core + service revenues + concessional grants).

Objectives and Use-Cases

The DMIA is designed to provide decision-relevant intelligence to four principal user groups. For the KRG and line ministries, it would support forward supply–demand balances, import timing and volumes, subsidy targeting, drought and pest early warning, and contingency-budget scenarios. Producers and cooperatives would receive near-real-time price signals, localized weather and planting windows, pest and disease alerts, input-price comparisons, and logistics options. Financial institutions and agribusinesses would gain access to spatial risk–return analytics, farmer-registry and yield-history inputs for credit assessment, site-selection intelligence for cold chains and processing, and trade-corridor analysis. Public-facing access to verifiable, privacy-protected datasets would additionally strengthen accountability, research, and innovation.

System Architecture

1. Data Acquisition and Integration
    a. Sources: employs a hybrid cloud architecture, sovereign on-site replication, and role-based encryption to protect stored and transmitted data.
    b. Pipelines: streaming and batch ETL; geographic tiling for remote sensing; data quality standards (completeness, timeliness, and outlier assessments).
    c. Standards: include ISO 19115 for metadata, OGC WMS/WFS for ecoservices, DCAT for catalogues, and GS1 for product identifiers, alongside multilingual tagging in Kurdish, Arabic, and English.

2. Data Governance and Analytical Insights
    a. Storage: incorporates a hybrid cloud strategy reinforced by sovereign on-premises replication, alongside the implementation of role-based encryption for data both at rest and in transit.
    b. Models: yield forecasting incorporating meteorological data, NDVI, and phenology; drought indices; pest risk assessment models; price nowcasting; simulations for import needs; and logistics cost surfaces.
    c. Versioning/Reproducibility: model registry, audit trails, and automated back testing to publish forecast error bands (goal in 5.8).

3. Apps/Services
    a. Policy Dashboards Assess: supply-demand equilibrium, import timing, subsidy allocation, and contingency activation points.

b. Farmer and Cooperative Tools: USSD, SMS, and mobile applications facilitate billing, weather predictions, and advisory services, with offline synchronisation capabilities for remote regions.
c. Investor and Lender Portals: Site selection visuals (cold storage, silos, processing units), risk assessment layers, and feasibility evaluation templates.

4. Governance and Access

a. Access Controls: Implement tiered roles that encompass public open data, registered farmers or cooperatives, institutional users, and premium analytics for private entities.
b. Data Sharing Instruments: Development of memoranda and legal requirements to facilitate interoperability among ministries; implementation of accreditation processes for private data providers.
c. Privacy and Ethics: Implementation of differential privacy methods for microdata, maintaining transparency in the consent process for the farmer registry, and establishing clear disclosure policies concerning algorithm updates.

5. Inquiry, Assessment, Advancement

a. Data: Cohort data collection encompasses user engagement metrics, response durations, platform accessibility, and data recency.
b. Impact KPIs: forecast error, import expenditure avoided, income effects, investment mobilized, spatial coverage.
c. Learning Loops: quarterly model recalibration; annual public "State of Agricultural Markets" report.

Data Governance and Legal Foundations

To avoid the "pilot graveyard, a statutory basis is needed for the DMIA:

1. Enabling Law/Decree: establishes data-sharing mandates, the custodian authority (DAA), and protections for personal and commercially sensitive data.
2. Interoperability Regulation: sets schemas, APIs, and update cadences; links ministry budget lines to compliance.
3. Bias and Access: Defaults to openness for non-sensitive aggregates; embargoes, licenses.
4. Procurement Neutrality: vendor-agnostic architecture, competitive tenders, no proprietary lock-in clauses, open API requirements for all contractors.

Institutional Anchor: DAA

There are MoAWR, Planning, Trade, farmer unions, academia, and the private sector, who form the independent board of the DAA, which reports to the Council of Ministers.

Core Functions

1. Custody of standards, registry, and accreditation; operation and evolution of the DMIA.
2. Convening role across ministries/donors; integration of legacy systems; publication of intelligence bulletins.
3. Compliance enforcement (interoperability, data quality); stewardship of privacy and ethics policies.

Financing

1. KRI core line-item within the Medium-Term Expenditure Framework;
2. Time-bound multi-donor trust fund for setup and capacity;
3. Cost recovery via premium analytics for banks, logistics firms, and exporters (transparent tariff schedule).

Staffing: civil-service core with protected technical pay bands; embedded fellows (universities) and secondments (extension services) to avoid skills bottlenecks.

Feedback Dynamics and Data Flows

The DMIA formalizes the exchange of two-way data.

1. Bottom-up: farmers/cooperatives use low-friction routes to report planting, pests, and yields, while extension personnel verify samples.
2. Top-down: DMIA produces ministry policy dashboards and customised advisories (planting windows, pest alerts, price trends).

Logistics companies and lenders add anonymised performance metrics (loan repayment, storage occupancy) to risk layers. Together, these flows close the observation–analysis–action loop and reduce the time between climate or market signals and policy response.

Efficiency and Cybersecurity

1. Security: measures include least-privilege access, penetration testing, geo-redundant backups, and zero-trust architecture.
2. Continuity: incident runbooks, seasonal RTO/RPO targets, and model update sandboxes.
3. Quality: structured data quality SLAs and provider scorecards; independent annual method and result audits for credibility.

Interoperability and External Alignment

The DMIA is designed to plug into interested partners. Hand-in-Hand geospatial services, the World Bank Agriculture Observatory, regional trade and customs interfaces, and potential federal Iraq agriculture observatories.

Alignment with SDG 2/9 and climate finance taxonomies (GCF/IFC) improves eligibility for concessional funding.

Implementation Dependencies

Execution hinges on (i) the DAA's legal mandate and ring-fenced funding; (ii) rapid consolidation of priority datasets and weather stations; (iii) change management embedded in extension services; and (iv) a staged release plan (pilots → scale), with hard gates tied to the KPIs in 5.8. Section 6 details the sequencing, budgets, procurement model, capacity plan, and risk register.

Conclusion

Changes in Agricultural Management Policy in the Kurdistan Region: Towards a Predictive Strategy

The Kurdistan Region is at a decisive stage; a change in agricultural management is underway, in which the policy of "temporary reaction" to crises is being ended and replaced by a proactive and intelligent strategy. The establishment of the "Digital Market Information Mapping" (DMIA) and the "Digital Agricultural Authority" (DAA) is not only a technological change but also a fundamental change in its management philosophy. According to the study, data fragmentation and institutional isolation have made our agricultural sector constantly vulnerable to market threats and climate change.

This new system will help the KRG, through inter-ministerial coordination, predictive analysis and data integration, formulate an agricultural policy that strikes a balance between social justice, environmental protection and fiscal responsibility. This mapping is not only technically important but also has a high price tag in terms of overall trust; it revitalises trust between government, investors and rural farmers and makes institutional responsibility the basis for decision-making.

The design of this system is based on the theories of "socio-technical change" and "adaptive management" to suit the economic and political realities of the region. With sustained political will, transparency and broad participation, this reform could make the Kurdistan Region a leader in digital agricultural management in the region. We hope this project will serve as a practical roadmap for developing regions to regain control of their food systems through information. Combining ethics, policy, and technology, DMIA and DAA make agricultural data a national asset to serve all.

Recommendations and Implementation Roadmap

Overview

More than technology, the Kurdistan Region of Iraq (KRI) needs institutional realignment, legal reform, and human capacity transformation to become a data-driven agricultural economy. The present paper presents a comprehensive implementation roadmap for the Digital Market Intelligence Architecture (DMIA) and its institutional foundation, the Digital Agriculture Authority.

The roadmap balances political economy constraints with international best practices, emphasizing sequencing, accountability, and realism. The five-year plan has three phases: System Foundations, Integration and Expansion, and Consolidation and Sustainability.

Strategic Justification

The DMIA–DAA system addresses three linked policy objectives. First, food security and fiscal stability require lower dependence on emergency imports and more precise subsidy allocation. Second, market transparency and inclusion require reliable information on prices, weather, and demand so that smallholders and cooperatives can make better production and marketing decisions. Third, agricultural investment requires credible and predictable evidence on risks and returns. Together, these objectives align the proposed reform with KRI development priorities, Iraq's agricultural policy framework, and Sustainable Development Goals 2, 9, and 13.

Guiding Implementation Principles

Implementation of this project requires adherence to six complementary strategic principles:

First, phased realism: Reform should begin on high-value data that quickly shows tangible results, rather than trying to make a sweeping change all at once.
Second, institutional embeddedness: technical functions should be given permanent status and continuity through legislation and guidance.
Third, integrate information into design: a common standard should be established from the outset to prevent the creation of disparate and fragmented donor systems.
Fourth, public-private co-production: Allow banks, telecommunications companies and the agri-technology sector to participate in innovation and services, without weakening the government's oversight authority over key data.
Fifth, transparency and benefit demonstration: The practical benefits of the system should be clear to ministries, farmers and investors from the outset, as this is the only way to build sustainable trust.

Sixth, sustainable financial management. The temporary assistance from donors and revenues from commercial services should be used to support a predictable overall budget to ensure the sustainability of the project.

Phase I: System Foundations (Year 1–2)

Objective: Establish the legal, institutional, and technical groundwork for DMIA and DAA.

A. Legal and Institutional Framework

1. Formulate and implement the KRI Digital Agriculture Law, outlining.
   a. The DAA mandate, the composition of the board, and the established lines of accountability.
   b. Obligations regarding data sharing for governmental ministries and private entities.
   c. Guidelines concerning data privacy, consent, and security protocols.
2. Form the DAA Board in conjunction with the Executive Secretariat.
3. Develop data-sharing agreements with the pertinent ministries: Agriculture, Trade, Finance, and Planning.

B. Data Infrastructure and Priority Datasets

1. Complete a data inventory audit mapping all agricultural, climate, and market data repositories in the region.
2. Establish the centralized data catalog and metadata registry according to ISO 19115 standards.
3. Deploy 10 automated weather stations in under-monitored districts (Sulaymaniyah, Halabja).
4. Set up a cloud infrastructure with secure data replication in Erbil and Duhok.

C. Quick-Win Applications.

1. Deploy Agri-Dashboard Beta to include all of:
   a. Production statistics for wheat and horticulture.
   b. Monthly price monitoring in major wholesale markets.
   c. Drought early-warning indicators.
2. Pilot SMS Advisory Service for 1,000 farmers in cooperation with telecom operators.
3. Provide training to 40 government analysts in geospatial analysis and data governance.

D. Financial Assistance and Strategic Partnerships

1. Obtain preliminary financing via a Multi-Donor Trust Fund.
2. Allocate USD 3.5 million for infrastructure development, legal drafting, and capacity-building initiatives.
3. Obtain in-kind donations from universities (data science programs) and telecoms (SMS gateway services).

E. Expected Outputs

7.5 Phase II: Integration and Development (Years 2–4)

Objective: Consolidate inter-ministerial datasets, augment analytical capabilities, and broaden user interaction.

A. System Integration

1. Transfer and standardize data from five primary ministries to the DMIA platform.
2. Develop interoperability connectors with:
a. Engaged partners Hand-in-Hand portal (for worldwide comparability).
b. Iraq Federal Agricultural Statistics Office (for national integration).
3. Establish a comprehensive farmer and cooperative registry, georeferenced and integrated with the social registry system.

B. Predictive and Analytical Components

1. Implement AI-driven yield prediction models utilizing Normalized Difference Vegetation Index (NDVI) and rainfall data.
2. Create a 'Data for All' Fellowship Program to link DAA data labs with local colleges.
3. Develop analytical methods to forecast market demand by leveraging historical price elasticities and consumption patterns.
4. Create a system to model agricultural fiscal risks that connects the probabilities of crop failure to their financial impacts.

C. Merging the Financial Ecosystem with the Private Sector

1. Develop a comprehensive investor intelligence gateway that provides:
a. Market trends, availability of water resources, and maps for land use classification.
b. Investment scorecards modified to account for risk (IFC).
2. Partner with banks and microfinance groups to provide data-driven agricultural financing solutions based on farmer registration scores.
3. A standard data API should be developed to help Agri-tech enterprises provide additional services such as insurance, logistics, and traceability.

D. Strategies of Transparency in Public

1. Publish quarterly agricultural market bulletins with price, import, and production summaries.
2. Create an open data portal (Kurdish, Arabic, and English) for non-sensitive datasets.
3. Establish a Data for All Fellowship Program to connect DAA data labs with local colleges.

E. Combining Capacity and Governance

1. Establish 60 DAA staff members with cybersecurity, GIS, and data engineering knowledge.
2. Establish a Performance Accountability Framework (PAF) to ensure accurate collection of data and timely response to its needs.
3. Use citizen scorecards and annual independent audits to ensure platform openness.

F. Financing Requirements
G. Expected Outputs
7.6 Phase III: Consolidation and Sustainability (Years 4–5)
Objective: Institutionalize DMIA operations, secure fiscal sustainability, and mainstream predictive governance.
A. Consolidation of Institutions
1. Designate DAA as a permanent statutory entity with an independent budget.
2. Implement data interoperability standards via ministerial directives.
3. Establish compliance-oriented financial incentives for ministries to disseminate data.

B. Economic Feasibility
1. Implement tiered subscription services: a) Offer complimentary public dashboards for basic data access.
2. Advanced analytics for financial institutions, traders, and insurance firms (cost recovery).
3. Obtain annual core funding of USD 2.5 million under KRI's Medium-Term Expenditure Framework.
4. Create an innovation fund to finance private-sector initiatives employing DMIA data.

C. Prevailing Policy
1. Integrate DMIA analytics into the development of the annual agricultural budget and import policy decisions.
2. Designate the Market Intelligence Report as a cabinet reference document.
3. Integrate DAA outcomes with national Sustainable Development Goals and climate adaptation reporting.

D. Regional diplomacy and collaboration
1. Collaborate with Turkey, Iran, and the Federal Government of Iraq to exchange data for cross-border business analysis.
2. Designate KRI as a regional centre for food market intelligence and resilience strategy development.
E. Performance Review and Evaluation
1. Conduct a five-year independent evaluation (coordinated by Interested partners and Vision Foundation for Strategic Studies).
2. Assess fiscal savings, yield stability, and private investment flows.
3. With the permission of the partners, publish open evaluation results and host a regional policy symposium.

Figure 6. *Monitoring and Evaluation Framework for DMIA–DAA Implementation Risk Assessment and Mitigation*

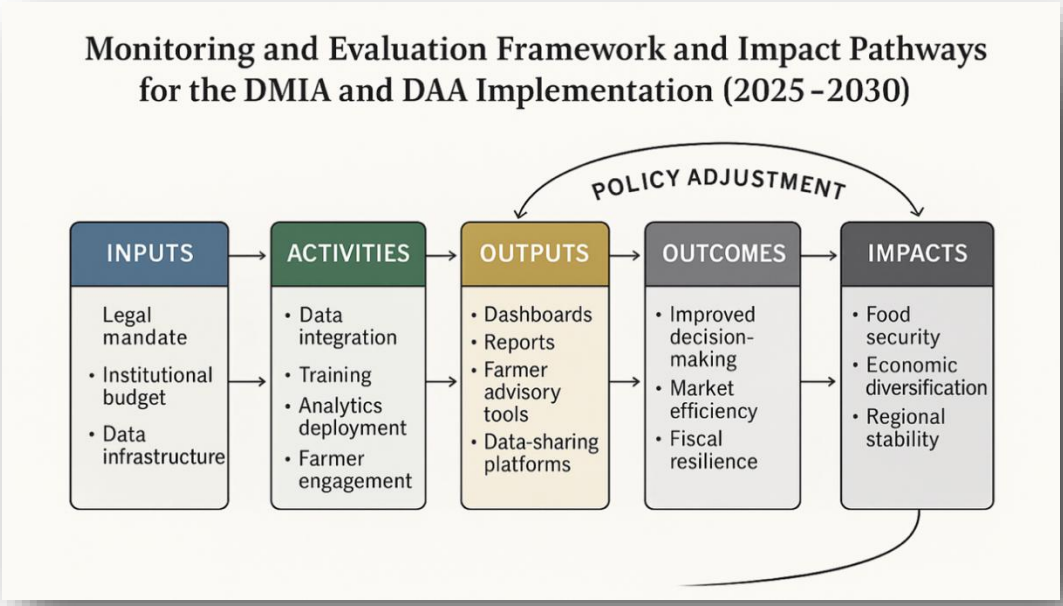


Table 1. *Risk and Mitigation Framework Implementation Timeline Overview*

Table 2. *Three-Phase Implementation Timeline*

Phase	Key Milestones	Timeframe
I. Foundations	DAA established; legal framework enacted; pilot dashboard launched	Year 1–2
II. Integration & Expansion	Inter-ministerial data integration; predictive modules operational	Year 2–4
III. Consolidation& Sustainability	Full institutionalization and regional interoperability	Year 4–5

Cross-Cutting Recommendations

Capacity development should institutionalise continuous professional learning through collaboration between the DAA, local universities, and relevant partners. Certification pathways in geographic information systems, machine learning, and agricultural economics should be complemented by designated data-stewardship roles in each participating ministry. This would create an internal network capable of maintaining data quality, interoperability, and analytical practice beyond the initial implementation period.

Inclusion should be embedded in system design rather than treated as a separate social component. DMIA reporting should be disaggregated by gender where data permit, while digital-literacy programmes and partnerships with civil-society organisations should improve access to training and finance for women farmers, young producers, and cooperatives. Low-bandwidth channels

such as SMS and USSD remain important safeguards for users in areas with weaker connectivity.

Environmental sustainability should also be integrated into the analytical core of the system. DMIA data can support climate-adaptation and water-management planning, satellite-based monitoring of soil degradation and vegetation conditions, and agricultural indicators relevant to Iraq's nationally determined contribution under the Paris Agreement. These functions would connect market intelligence with longer-term resource resilience.

Strategic communication should sustain institutional legitimacy through multilingual quarterly market bulletins, transparent publication of non-sensitive indicators, and a clear DAA identity centred on trust, innovation, and accountability. Communication should explain not only what data are collected, but how those data improve decisions for farmers, public institutions, and investors.

Role of Vision Foundation for Strategic Studies

VFSS will provide knowledge and evaluation during DMIA implementation. Roles include:

1. Policy Research and Impact Evaluation: Independent assessments of DMIA productivity, budget management, and equality.
2. Strategic Foresight: Using scenario planning and modeling to anticipate geopolitical and climate-related disruptions to KRI's agri-food system.
3. Capacity Building: Data-driven governance executive training for policymakers and DAA officials.
4. Regional Thought Leadership: annual "Digital Resilience in Agriculture" study and regional symposia to establish KRI as a Middle Eastern digital innovation leader.
5. Critical and strategic tasks of VFSS remain DMIA evidence-based, politically credible, and regionally influential.

Long-Term Impact

By 2030, successful implementation should be assessed against a limited set of strategic outcomes rather than technological deployment alone. The reform is intended to contribute to higher agricultural value added through productivity gains and lower post-harvest losses; reduce emergency-import exposure by approximately 20%; support substantial improvements in farmer income; mobilise domestic and international private investment around data-enabled agricultural services and infrastructure; and institutionalise predictive early-warning capacity for drought, production, and price shocks. These targets remain policy objectives to be validated through the monitoring and evaluation framework rather than guaranteed causal effects.

Abbreviations List

Abbreviation	Full Term
AI	Artificial Intelligence
API	Application Programming Interface
ATA	Agricultural Transformation Agency (Ethiopia)
DAA	Digital Agriculture Authority
DCAT	Data Catalog Vocabulary (Metadata Standard)
DMIA	Digital Market Intelligence Architecture
ETL	Extract, Transform, and Load
FAO	Food and Agriculture Organization of the United Nations
FAOSTAT	FAO Statistical Database
GCF	Green Climate Fund
GFSI	Global Food Security Index
GIS	Geographic Information System
GS1	Global Standards One (Product Identification System)
IFC	International Finance Corporation
IFPRI	International Food Policy Research Institute
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KRI	Kurdistan Regional Government
KRI	Kurdistan Region of Iraq
MAPE	Mean Absolute Percentage Error
MEL	Monitoring, Evaluation, and Learning
MoAWR	Ministry of Agriculture and Water Resources (KRI)
MoF	Ministry of Finance (KRI)
NDVI	Normalized Difference Vegetation Index
NDC	Nationally Determined Contribution
OGC	Open Geospatial Consortium
PAF	Performance Accountability Framework
SDG	Sustainable Development Goal
SMS	Short Message Service
UNDP	United Nations Development Programme
USD	United States Dollar
VFSS	Vision Foundation for Strategic Studies
WFP	World Food Programme
WMO	World Meteorological Organization
WTO	World Trade Organization

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