Report

Situation Analysis: Raichur Transformation Lab

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CLARE Climate Adaptation & Resilience
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Cover Image A farmer tilling a field with bullocks in Devadurga taluk, Raichur district. Photo by Nabina Chakraborty

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About CLARE

CLARE is a UK-Canada framework research programme on climate adaptation and resilience, aiming to enable socially inclusive and sustainable action to build resilience to climate change and natural hazards. CLARE is an initiative jointly designed and run by the UK Foreign, Commonwealth and Development Office and Canada's International Development Research Centre. CLARE is primarily funded by UK aid from the UK government, along with the International Development Research Centre, Canada.

About CLARITY

Climate Adaptation and Resilience in Tropical Drylands (CLARITY), a research project under CLARE, is building equitable, sustainable, and climate-resilient development pathways in tropical drylands. This Global South-led project will result in the creation of long-term assets (data and tools) and capacities to achieve transformational change.

CLARITY focuses on Transformation Labs (T-Labs) in Niger-Nigeria, Tanzania, and India. These labs are collaborative spaces for communities and researchers to develop sustainable, equitable pathways. In India, we are establishing two Transformation Labs in semi-arid regions in the state of Karnataka: Chikkaballapur-Chintamani and Raichur. Both are at the urban-rural interface and are characterised by shallow and deep aquifers that have been rapidly depleting for almost two decades.

Our approach is solutions-focused and transdisciplinary. We are:

1. Co-constructing narratives of water management with marginalised groups based on video diaries and interviews, training para-hydrogeologists in the community, and collecting and analysing data for local action.

2. Using the narratives and data to build models that generate disaggregated and technically, socially plausible pathways.

3. Engaging with key changemakers to ensure the research gets embedded in wider policy processes and communities of practice by sharing tools, training materials, interactive reports, and games.

About WELL Labs

Water, Environment, Land and Livelihoods (WELL) Labs co-creates research and innovation for social impact in the domains of land and water sustainability. We design and curate systemic, science-based solutions using a collaborative approach to enable a high quality of human life while simultaneously nurturing the environment.

WELL Labs is based at the Institute for Financial Management and Research (IFMR) Society. Together with Krea University and other centres at IFMR, such as the Abdul Latif Jameel Poverty Action Lab (J-PAL) South Asia and Leveraging Evidence for Access and Development (LEAD), WELL Labs is part of an ecosystem of labs and research centres with a mission to help prepare for an unpredictable world.

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Executive Summary

Despite government efforts to expand irrigation infrastructure, Raichur district[1] in the Indian state of Karnataka faces significant water management challenges, which threaten agricultural productivity and farmer livelihoods. This situation analysis report examines the root causes and contextual factors behind these water management problems.

Rainfall patterns in Raichur have become increasingly erratic due to climate change, with the district experiencing variable rainfall and frequent dry spells over the last decade. These are expected to worsen as climate change intensifies.

Groundwater resources are limited, with fluoride and salinity contamination in many areas. While irrigation projects like the Narayanpur Right Bank Canal and Tungabhadra Left Bank Canal provide surface water, its distribution is highly inequitable—head-end farmers capture most of the water, while tail-end farmers receive little.

Moreover, the transition to water-intensive crops like paddy, supported by government incentives, has led to the overexploitation of water resources and land degradation through waterlogging and soil salinisation. Inadequate drainage infrastructure and a lack of mechanisms for equitable water sharing further compound these problems.

Broader socio-economic trends such as the fragmentation of landholdings, rising cultivation costs, stagnant wage growth, indebtedness, and ecological changes like land degradation have rendered agriculture economically unviable for smallholder farmers. This is driving distress migration and landlessness. Policy support through subsidies and cash transfers has been inadequate in addressing the root causes of these complex challenges.

However, pathways are emerging to address them in a holistic manner. The Government of Karnataka's canal automation project presents an opportunity for transformative change by empowering farmer groups with controlled water distribution. By mapping stakeholders in the region, we found that there is potential for innovative partnerships between government agencies, civil society, researchers, and communities to facilitate institutional mechanisms for equitable, sustainable water sharing.

Collaborative knowledge production processes like the journey mapping of farmers' experiences, rural livelihood aspirations studies, community visioning workshops, and stakeholder roundtables are key to making water-sharing institutions and policies effective. With strategic investments to facilitate and

[1] A district is an administrative subdivision of a state in India. It comprises several taluks (or talukas).

innovate solutions, reduce technology costs, and promote participatory irrigation management, Raichur could pioneer an equitable, climate-resilient model for water stewardship in agriculture.

1. The Raichur Transformation Lab

Raichur is a predominantly agricultural district with a significant population of pastoralist and agro-pastoralist communities.

It is located in the northeastern part of Karnataka state between 15° 33'- 16° 34' North latitudes and 76° 14'- 77° 36' East longitudes. The district lies between two major rivers, the Krishna and the Tungabhadra.

The state's 2022 Human Development Report mentions that the district fares poorly on several socio-economic indicators (Government of Karnataka, 2022). Of the two million people in the district, nearly 40% belong to Scheduled Caste[2] and Scheduled Tribe[3] social groups (Roy et al, 2015). NITI Aayog[4] classifies Raichur as an '[aspirational district]'[5].

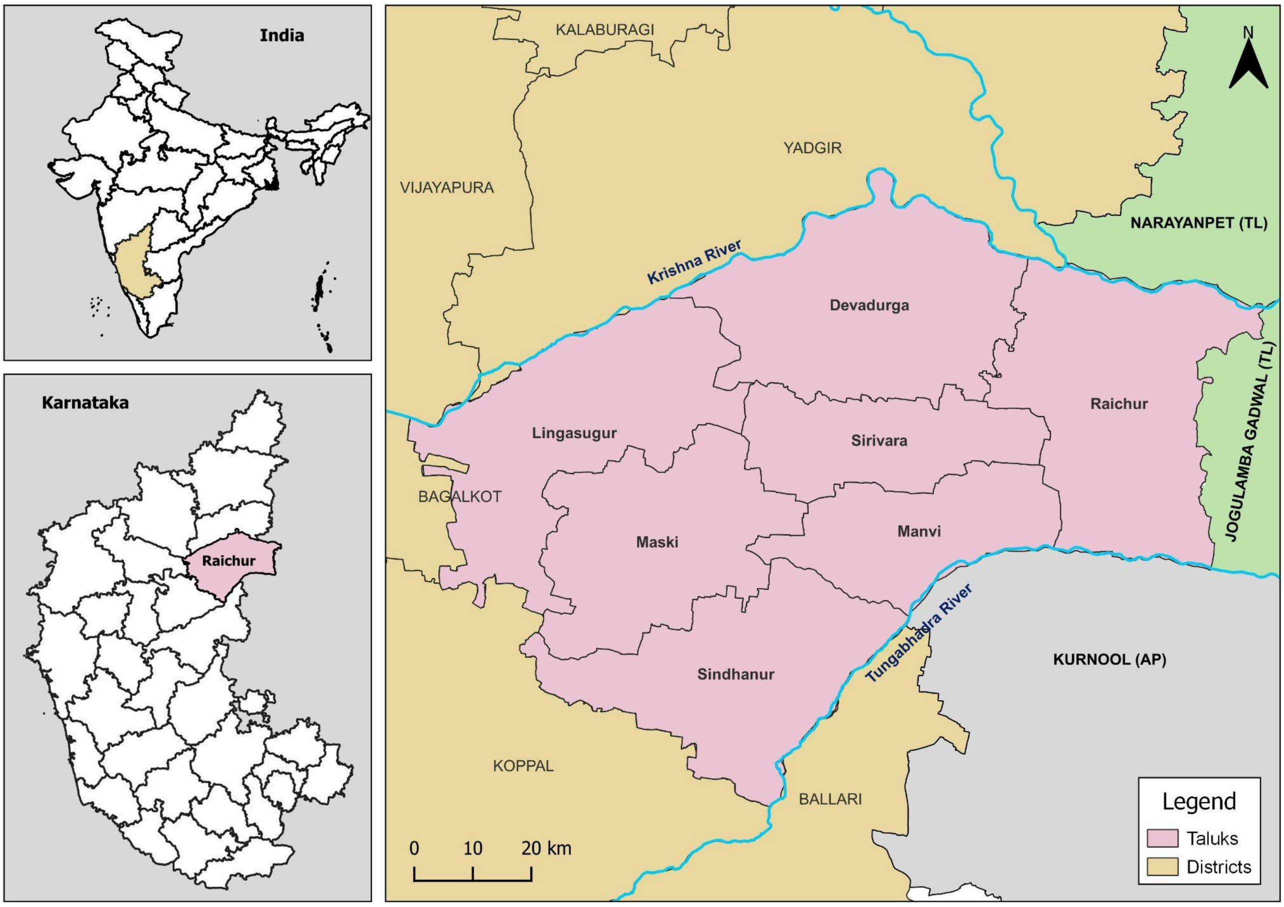

Figure 1: Raichur district map

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[2] The Constitution of India has designated certain marginalised castes as Scheduled Caste. The Government of India and states have affirmative action policies to benefit these groups

[3] The Constitution of India has designated certain indigenous communities as Scheduled Caste. The Government of India and states have affirmative action policies to benefit these communities.

[4] A Government of India policy think tank

[5] The Aspirational Districts Programme seeks to "quickly and effectively transform the 112 most under-developed districts across the country".

As per the 2011 census, nearly 80% of the population depended on firewood for cooking. Potential-linked credit plans developed by the National Bank for Agriculture and Rural Development (NABARD)[6] have identified goat and sheep rearing as prioritised credit-lending activities. Raichur also fares poorly in terms of child mortality rates, maternal mortality rates, household access to cooking fuels, literacy rates, pucca (solid and permanent) houses, and safe drinking water access.

1.1 Water Resources in Raichur

While 70% of Raichur's population depends on agriculture and allied activities for their livelihoods (District Census Handbook, 2011), water remains a limited resource.

Raichur has a net sown area of 4,750 sq. km, of which only 1,557.2 sq. km (around 33%) is irrigated. The land use land cover map of Raichur shows lands with single cropping, double cropping and triple cropping (Figure 2). A higher cropping intensity (more than one season of cropping) indicates water availability either in the form of soil moisture or irrigation water from surface or groundwater. Around 72% of the total irrigated area is supplied by canals and 16% by groundwater (Figure 3a).

There is a reduction in the area irrigated by canals between 1966-67 and 2019-2020 (Figure 3b), even though multiple irrigation projects were sanctioned during the 50-year period and the area irrigated by groundwater has increased considerably (Government of Karnataka, 1970). The reduction in canal-irrigated area, even when the total area under irrigation has increased, indicates inefficiencies in surface irrigation systems, such as the inequitable distribution of canal water.

[6] NABARD is India's apex development bank, established in 1982 under an Act of Parliament to promote sustainable and equitable agriculture and rural development.

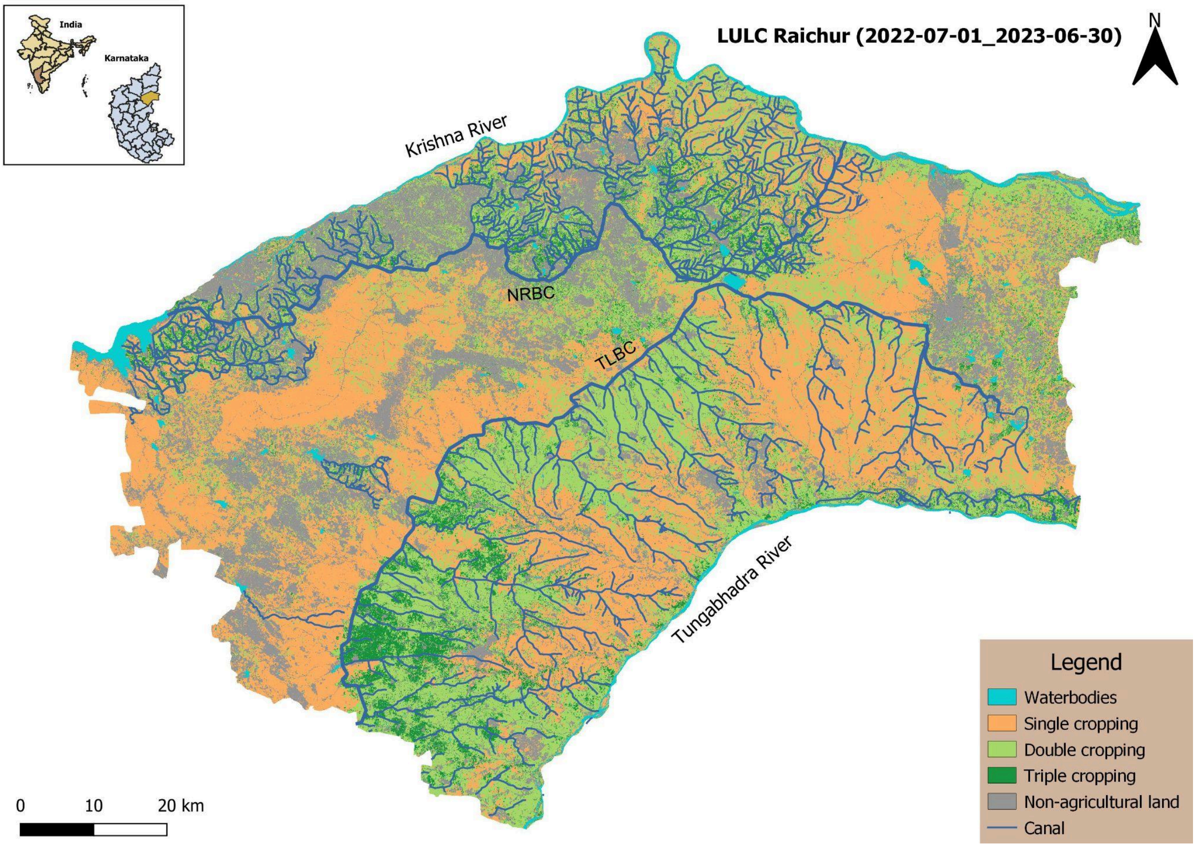

Figure 2: Land use land cover (LULC) maps developed by IIT and WELL Labs (2022-23)

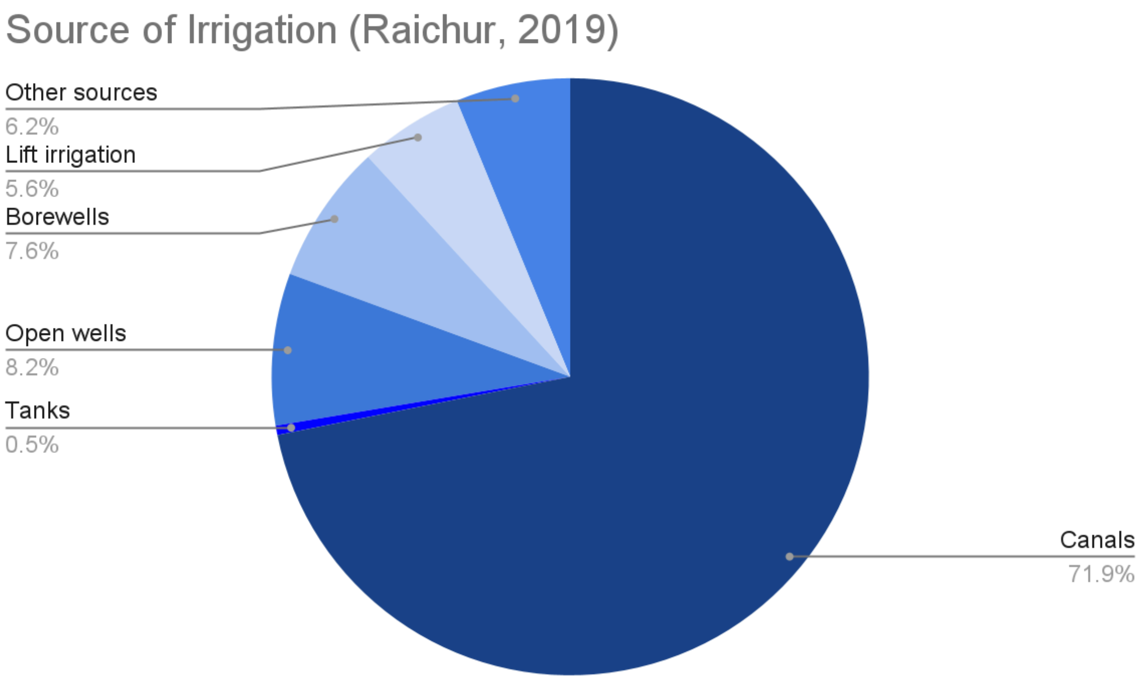

Figure 3a: Sources of irrigation in Raichur district. Source: Department of Agriculture and Farmers' Welfare, 2019-20

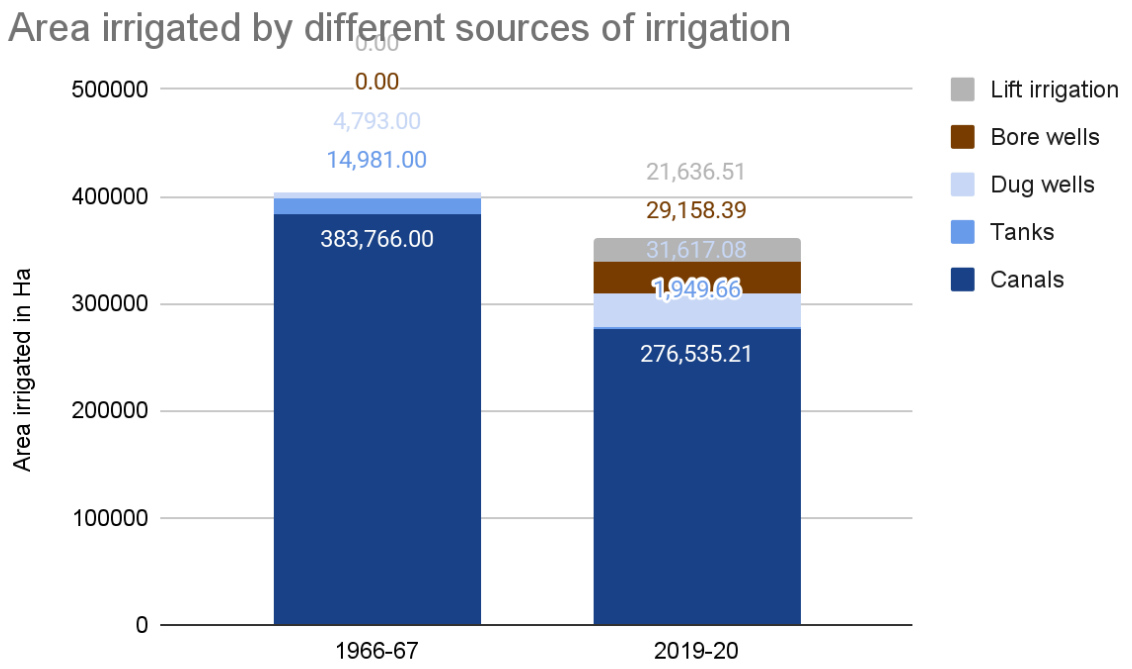

Figure 3b: Area of land under irrigation from different sources. Source: Department of Agriculture and Farmers' Welfare, 1966-67 and 2019-20

1.1.1 Rainfall

Raichur district falls within the 33% of the area in the country classified as chronically drought-prone.

Between 1951 and 2023, Raichur had an average annual rainfall of 645 mm, with a discernible decreasing trend in annual precipitation. Erratic rainfall patterns with high inter-annual variability (ranging from 335 to 1,329 mm) characterise the precipitation in the region (Pai et al., 2014).

Since 2014, the district has experienced unpredictable and diminishing rainfall. In 2018, the Karnataka State Natural Disaster Monitoring Centre (KSNDMC) declared Raichur to be in the grip of a severe drought (Pal et al., 2022).

To assess the projected impact of climate change on the region, downscaled debiased datasets covering the Indian subcontinent (Mishra et al., 2020) were utilised.

The climate predictions are driven by Shared Socioeconomic Pathways (SSPs) scenarios and future social development pathways (O'Neill et al., 2016). SSPs are based on five narratives describing alternative socioeconomic developments, including sustainable development, regional rivalry, inequality, fossil-fuelled development, and middle-of-the-road development (Riahi et al., 2017). These datasets, representing four scenarios (SSP126, SSP245, SSP370, and SSP585) forced in the CMIP6 model, were used in the situation analysis.

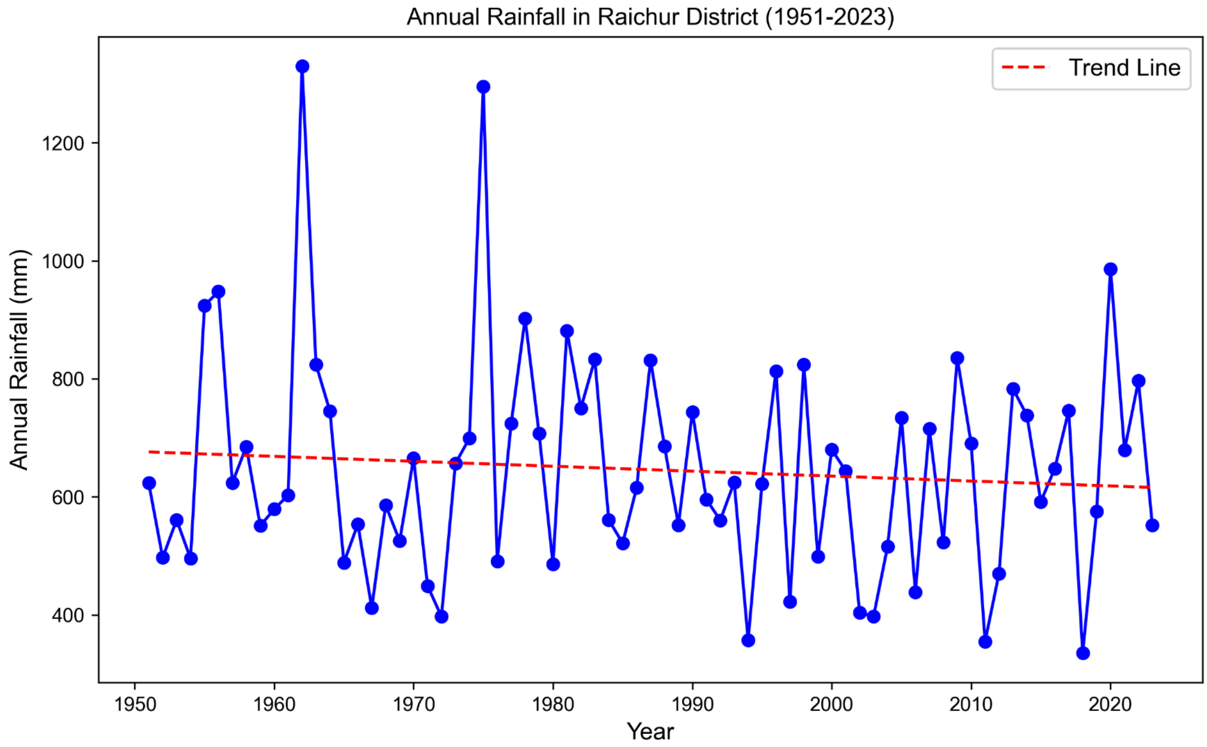

Figure 4: Annual Rainfall in Raichur district (1951-2023). Source: Pai et al., 2014

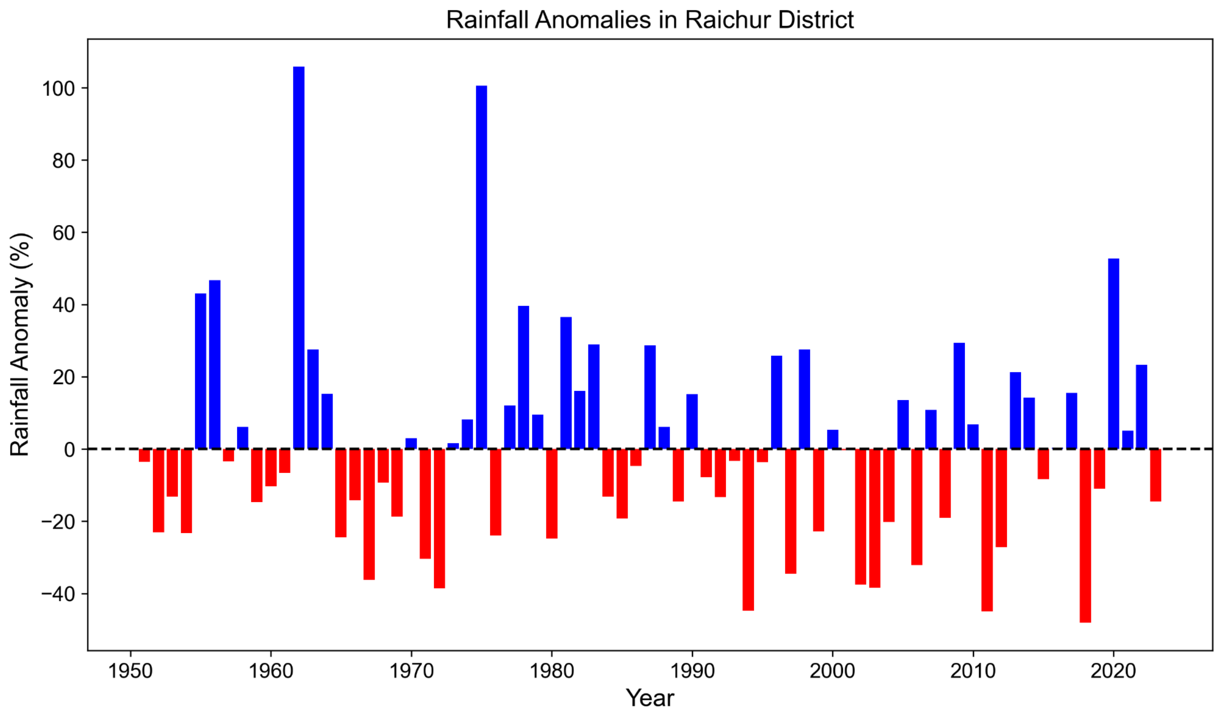

Figure 5: Rainfall anomalies in Raichur district. Source: Pai et al., 2014

The projected precipitation trends exhibit pronounced inter-annual variation and the precipitation range varies according to these scenarios.

However, compared to the historical period, future projections show an overall increasing trend in precipitation. All projected climate scenarios indicate a rise in extreme precipitation events in the region.

Temperatures have also exhibited a rising trend in Raichur. The average maximum temperature rose by 0.68°C and the average minimum temperature by 1.0°C between 1951 and 2014 (Srivastava et al., 2009). In all projected climate scenarios, temperatures are expected to continue increasing. It is anticipated that the minimum temperature will rise more than the maximum temperature.

This elevated temperature, coupled with increasingly frequent and intense rainfall events, is likely to adversely impact agricultural outputs and the regional economy.

1.1.2 Groundwater

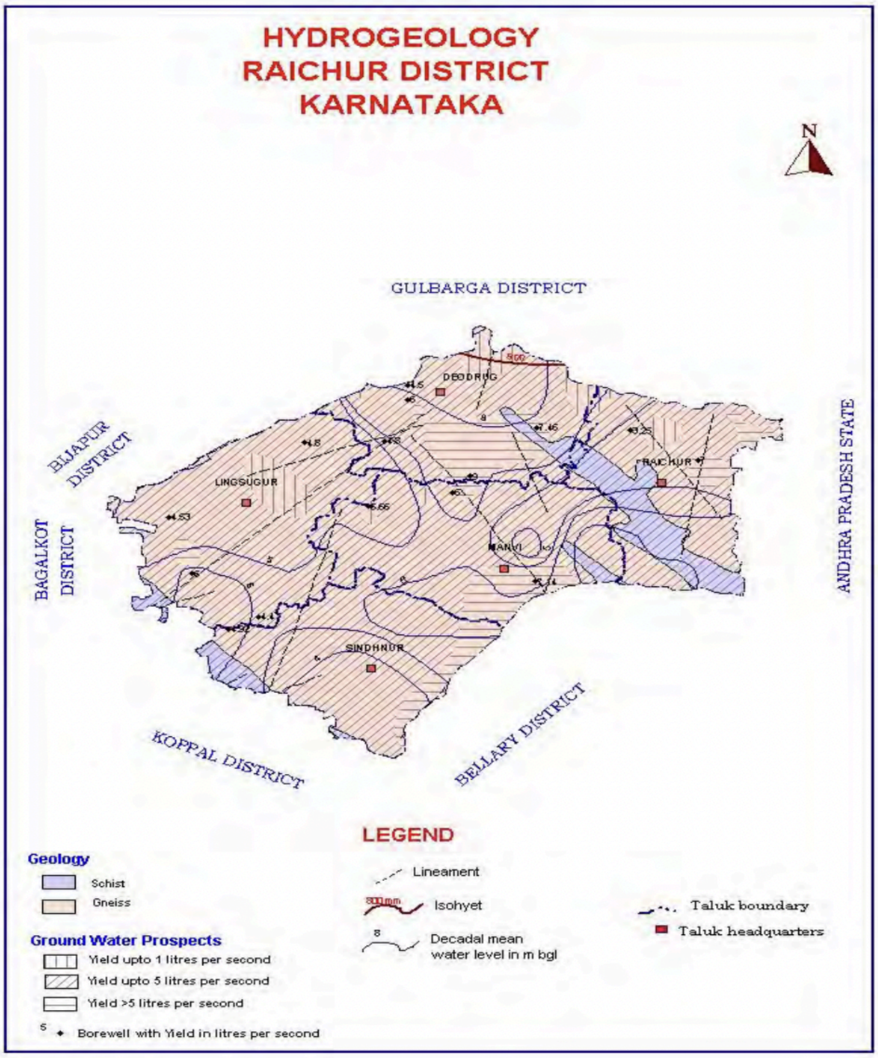

Figure 6: Hydrogeology of Raichur (Central Groundwater Board, 2013)

The hydrogeological conditions in Raichur district are predominantly influenced by the presence of crystalline hard rocks such as granites, gneisses, and Dharwar schists. The parent rocks are often overlain by a layer of weathered rocks formed by the conversion of bedrock (saprock) to regolith (saprolite). There is a layer of stratified fractured rocks below the weathered rocks. This secondary porosity enhances permeability and water retention capabilities (Central Ground Water Board, 2013). With increasing depth, the prevalence of fractures reduces in the bedrock (Lachassagne, 2021).

Groundwater is primarily found under water table conditions[7] within the weathered and fractured hard rock formations. The presence of two large canal systems leads to high groundwater recharge and shallow groundwater levels. Deeper fractures may contain water in semi-confined conditions.

There are pockets of high-salinity groundwater, especially in the southern parts of the district under the Tungabhadra Left Bank Canal's command area. The reason for salinity is unclear—it may be exacerbated by high-intensity surface water irrigation for over six decades. The prevalence of low-conductivity black soils across the district hinders the infiltration of diffuse recharge. Poor drainage conditions may have contributed to high salinity in certain areas.

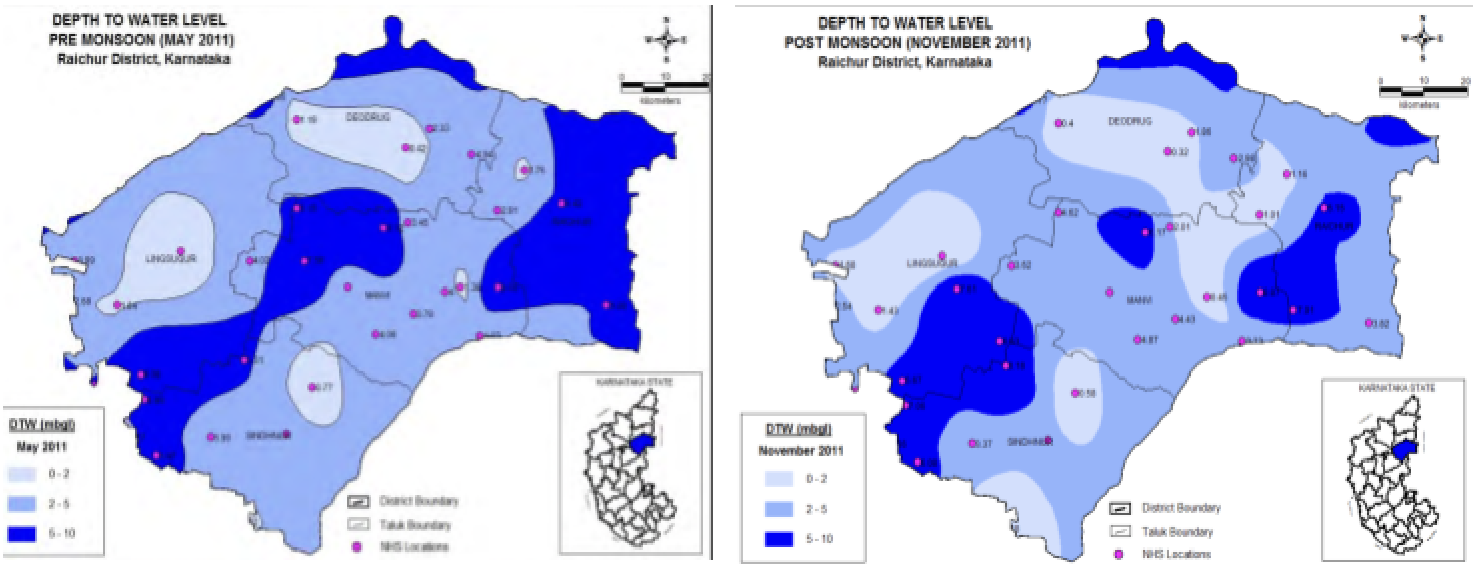

Figure 7: Depth to groundwater in Raichur district. Source: Central Ground Water Board, 2013

The depth to groundwater fluctuates between 0.4 metres below ground level (mbgl) to 8.3 mbgl during the pre-monsoon period and from 0.1 mbgl to 8.9 mbgl during the post-monsoon period. Over the decades, fluctuations between

[7] The US Geological Survey explains under water table conditions as follows: "Groundwater in aquifers between layers of poorly permeable rock, such as clay or shale, may be confined under pressure. If such a confined aquifer is tapped by a well, water will rise above the top of the aquifer and may even flow from the well onto the land surface. Water confined in this way is said to be under artesian pressure, and the aquifer is called an artesian aquifer... Where groundwater is not confined under pressure, it is described as being under water table conditions... Water-table aquifers generally are recharged locally, and water tables in shallow aquifers may fluctuate up and down directly in unison with precipitation or streamflow."

pre-monsoon and post-monsoon groundwater levels show both spikes and falls across various national hydrograph stations (NHS)[8].

Shallow aquifers, found primarily within weathered, semi-weathered, and partly fractured hard rocks up to approximately 30 mbgl, supply water mainly through dug wells, dug-cum-bore wells, and shallow bore wells (Central Ground Water Board, 2013). Medium to deep aquifers, located between depths of 30 to 100 mbgl, are tapped through bore wells and are crucial for drinking and irrigation. Only 5% of the district's groundwater is overexploited (Department of Agriculture and Farmers' Welfare, 2019).

Groundwater quality assessments indicate that water in most parts of the district meets potable standards and is suitable for irrigation (Central Ground Water Board, 2013). However, fluoride contamination is prevalent in many areas, leading to dental and skeletal health concerns. Its concentration ranges from 0.1 mg/l to 4.7 mg/l (maximum permissible concentration is 1.5 mg/l), which limits groundwater use.

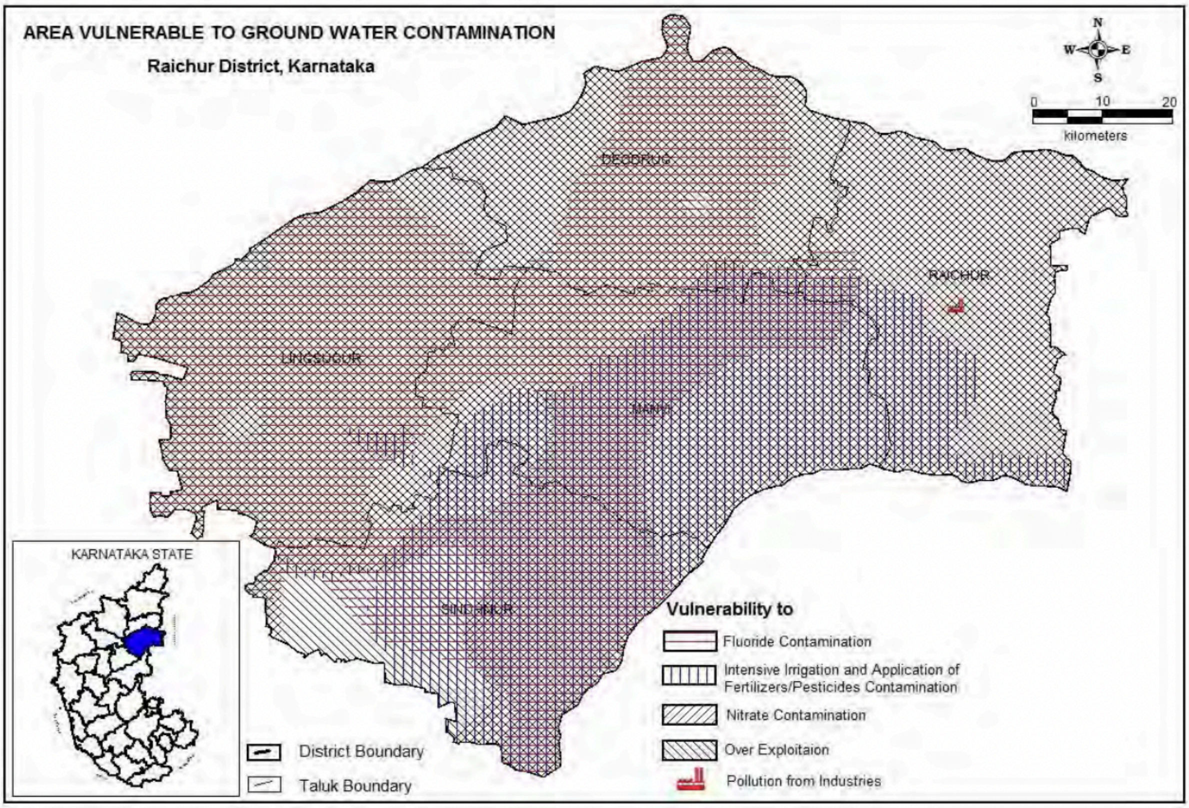

Figure 8: Areas vulnerable to groundwater contamination.
Source: Central Groundwater Board, 2013

Chemical analysis of groundwater samples reveals varying levels of electrical conductivity, chloride, and sodium absorption ratio (SAR), with instances of salinity

[8] For more information about these stations, see Dixit et al., 2024

in specific boreholes. Some areas, notably Lingasugur, Raichur, and Sindhanur taluks[9], experience salinity, rendering groundwater unsuitable for irrigation.

1.1.3 Surface Water

Raichur district is part of the larger Raichur doab[10] between the Krishna river and its tributary, the Tungabhadra. It falls entirely in the Krishna basin. The Krishna river, the third-longest in India and fourth in river basin area (Figure 9), passes through the states of Maharashtra, Karnataka, Telangana, and Andhra Pradesh. Around 43% of the river basin area (2,58,948 sq. km) is in Karnataka (Ministry of Water Resources, 2014).

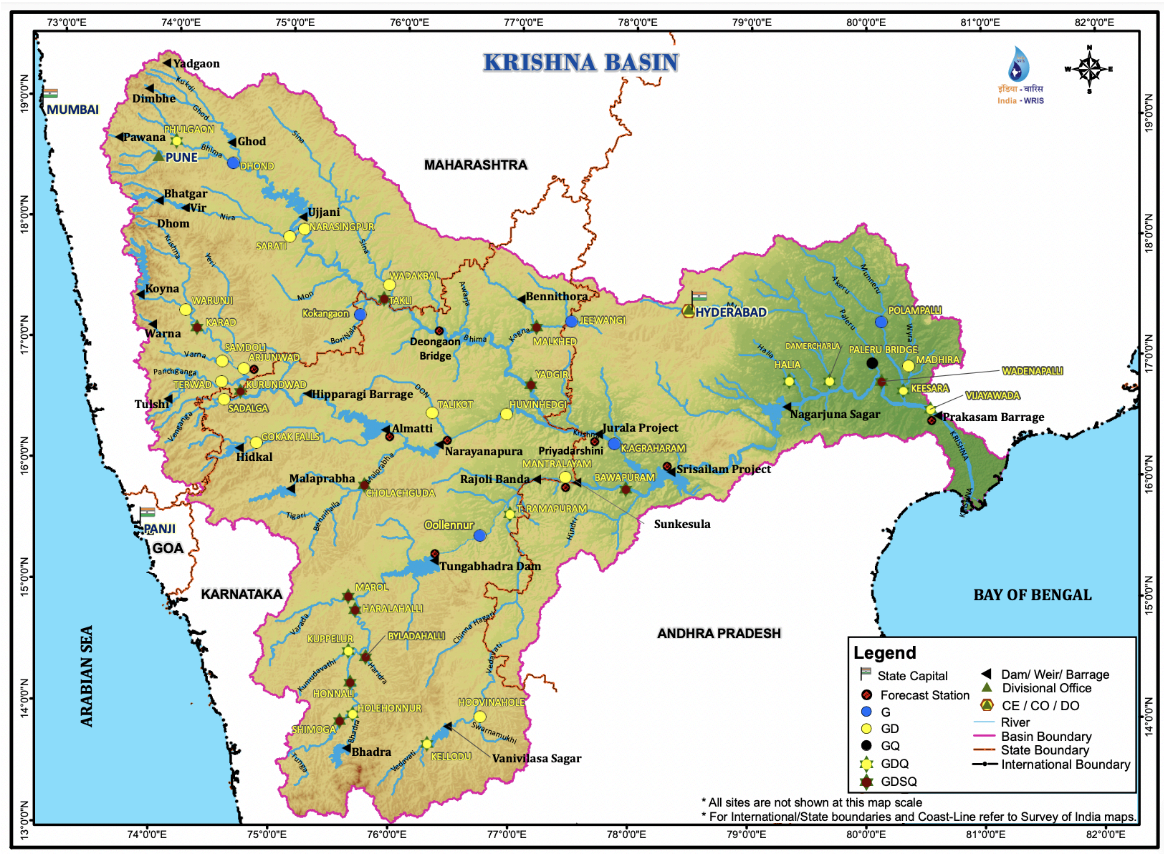

Figure 9: Krishna basin. Source: Ministry of Water Resources, 2014

Over the past few decades, Raichur and neighbouring regions became the 'rice bowl' of Karnataka owing to two irrigation projects—the Narayanpur Right Bank Canal and Tungabhadra Left Bank Canal. The former, part of the Upper Krishna Project, has a potential irrigation area of 840 sq. km and the latter has an irrigation potential of 2,500 sq. km.

The Upper Krishna Project, built in 1964, consists of two dams across the river Krishna and a network of canals. The main storage is at Almatti Dam, a few

[9] A taluk or taluka is an administrative subdivision of a district for revenue purposes. It comprises several villages.
[10] Doab refers to the land lying between two confluent rivers.

kilometres downstream of the confluence of the Ghataprabha and Krishna rivers. Downstream from it is the Narayanpur dam. Located a few kilometres downstream of the confluence of the Malaprabha and Krishna rivers, it serves as a diversion dam.

Medium-sized irrigation projects also serve Raichur district. These include the Chitwadgi Medium Irrigation Project, Hirehalla Medium Irrigation Project, Kanakanala Medium Irrigation Project, Maskinala Medium Irrigation Project, and Rajolibanda Irrigation Project.

Figure 10 merges the canal network layers with Raichur district elevation maps. It shows that the Narayanpur Right Bank and Tungabhadra Left Bank canals do not irrigate the areas between them as the latter are at higher elevations. Even within their command areas, the canals do not serve lands at higher elevations.

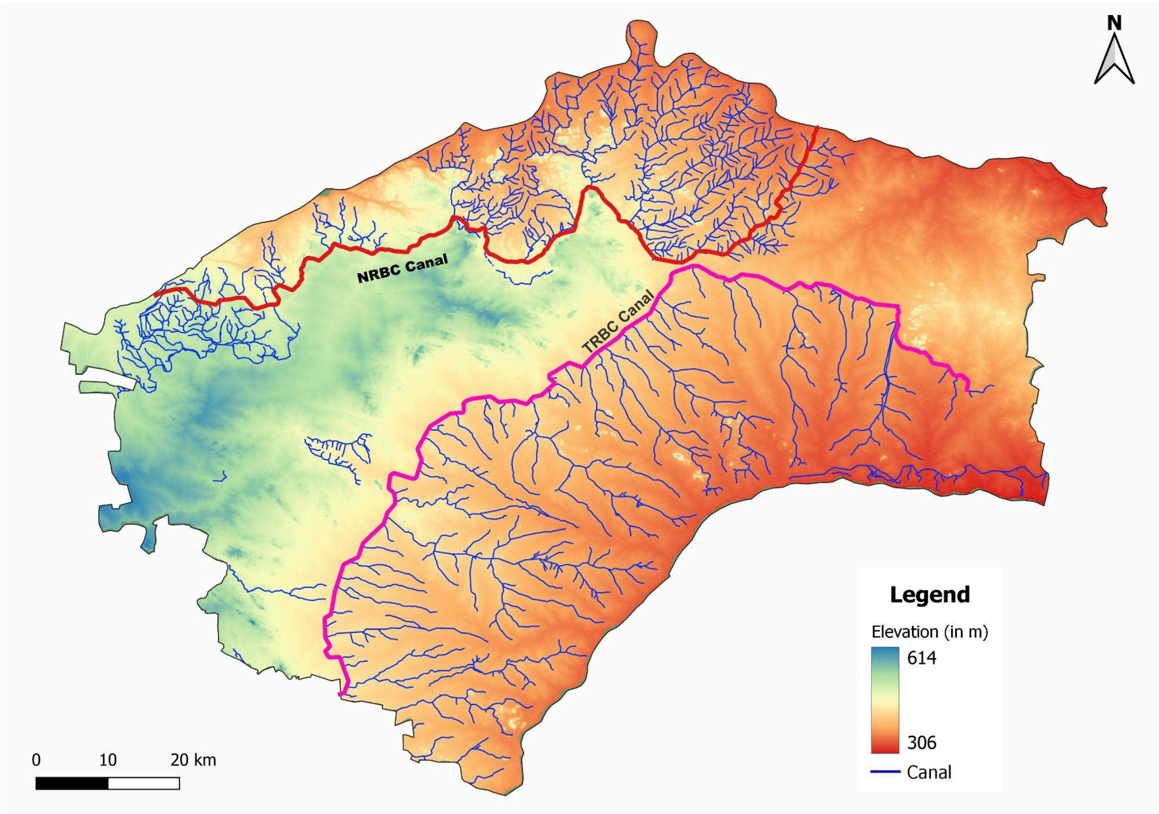

Figure 10: Irrigation canal network in Raichur (WELL Labs visualisation)

Irrigation Projects and Policies

The evolution of irrigation projects in Raichur district spans several decades, reflecting efforts to address the region's water challenges and enhance agricultural productivity.

Tungabhadra Project, 1944

The Tungabhadra Dam, initiated by the Madras and Hyderabad states of pre-Independence India in 1944, was a pioneering effort. Completed in 1958, it facilitated the creation of canal systems, including the Left Bank Main Canal (LBMC) and the Right Bank High Level Canal (RBHLC), to provide water for agriculture. These canals played a crucial role in supporting kharif season crops when rainfall was erratic (Karnataka Niravari Nigam Ltd, n.d.).

Lift Irrigation Schemes, 1960s

The state government established lift irrigation schemes in the northern part of Karnataka, including Raichur district. They aimed to mitigate the effects of perpetual drought conditions by lifting water from available sources to irrigate agricultural lands. However, they faced operational challenges, resulting in sub-optimal functioning and the underutilisation of their irrigation potential (Kulkarni & Bokil, 2003).

Karnataka Irrigation Act, 1965

The Karnataka Irrigation Act, 1965 marked a significant milestone in the regulation and management of water resources across the state. It provided a comprehensive legal framework for the development, distribution, and utilisation of water for irrigation. It also outlined provisions for the construction and maintenance of irrigation works, water licensing, and dispute resolution mechanisms, laying the groundwork for effective water governance in the region (Government of Karnataka, 1965).

Upper Krishna Project, 1970s

The Upper Krishna Project was a significant endeavour to harness the Krishna river for irrigation in Raichur district. It aimed to utilise allocated water shares as per the Krishna Water Dispute Tribunal's adjudication. Under the project, storage reservoirs and canal networks were constructed to optimise water distribution for agricultural use.

Krishna Bhagya Jala Nigam Limited, 1994

The Krishna Bhagya Jala Nigam Limited is a government-owned entity established in 1994 to oversee irrigation projects in Karnataka. It played a pivotal role in coordinating the various phases of the Upper Krishna Project, thereby ensuring the efficient utilisation of allocated water resources to meet the agricultural demands of Raichur and neighbouring regions.

Narayanpur Left Bank Canal Automation Project, 2014

The Government of Karnataka addressed issues in the Narayanpur Left Bank Canal irrigation system, including the lack of water regulation, inadequate maintenance, wastage, and inequitable water distribution (NITI Aayog, n.d.). Through the installation of more than 4,000 automated gates, software, and solar-powered systems, it enhanced water management along 1,500 km of canals, enabling efficient irrigation scheduling, equitable water distribution, increased agricultural production, reduced operational costs, and improved decision-making.

State Water Policy, 2022

Karnataka's water policy framework has evolved over the years to address the challenges of water scarcity, agricultural development, and sustainability. The state government has formulated policies that emphasise the efficient utilisation of water resources, promotion of water-saving technologies, and equitable water distribution for various sectors, including agriculture, industry, and domestic use. These regulations aim to balance competing water demands while ensuring the long-term sustainability of water resources across the state (State Water Policy, 2022).

Figure 11: Narayanpur Right Bank Canal

2. Water Management for Agriculture

Karnataka and its drought-prone districts like Raichur grapple with challenges in water resources management, particularly with respect to competing demands and vulnerability to climate change (Asian Development Bank, n.d.). This chapter explores the water management issues that Raichur faces and its impact on agriculture.

2.1 Inequitable Distribution of Canal Water

In many parts of the country, as dam infrastructure is built, incentives are aligned for farmers to switch to water-intensive crops.

They grow one or two paddy crops a year and use industrially produced fertilisers and pesticides. The same happened in Raichur with the construction of the Tungabhadra Left Bank Canal (TLBC) and Narayanpur Right Bank Canal (NRBC). Furthermore, since these projects were not designed to irrigate paddy, but for protective irrigation[11] to support dryland crops and horticulture, there is not enough water for all farmers to grow paddy.

Farmers closer to the dam (head-end farmers) capture most of the water, while those downstream (tail-end farmers) do not receive enough.

The head end of both the Narayanpur Right Bank and Tungabhadra Left Bank canals has land under double or triple cropping, whereas the tail-end largely grows one crop, especially in the case of longer distributaries (Figure 12). Tail-end farmers usually belong to more vulnerable and marginalised groups; they cannot improve their incomes unless they gain access to water.

There are similar trends for canal irrigation in other regions as well. Mishra et al. (2012) found insufficient water availability for paddy cultivation in the middle and tail reaches of the Eastern Yamuna Canal[12] during the kharif season, prompting farmers to switch to sorghum. Conveyance efficiencies of 43-44% suggest that there is potential to increase water availability along the canal by addressing seepage and evaporation losses.

Besides, there is a 'use it or lose it' mindset. Farmers tend to overuse water even when they don't necessarily need it because they cannot save it for later.

Head-end farmers do not necessarily want to overuse water, but they lack

[11] Protective irrigation systems are "designed and operated on the principle that the available water in rivers or reservoirs has to be spread thinly over a large area, in an equitable manner. The idea is to reach as many farmers as possible, and to protect them against crop failure and famine, which would regularly occur without irrigation in regions with low and erratic rainfall."

[12] The Eastern Yamuna Canal flows through four districts of western Uttar Pradesh, namely, Saharanpur, Muzaffarnagar, Baghpat and Ghaziabad.

incentives to not do so. The mechanisms and infrastructure for equitable water sharing were never established. Water is made available through the flooding of fields via feeder channels (The canal infrastructure is designed for flood irrigation even though it was not meant for paddy). Thus, farmers cannot install drip or other micro-irrigation systems. Moreover, regulations mandate that irrigation water cannot be stored locally for use in the dry season (Government of Karnataka, 1980).

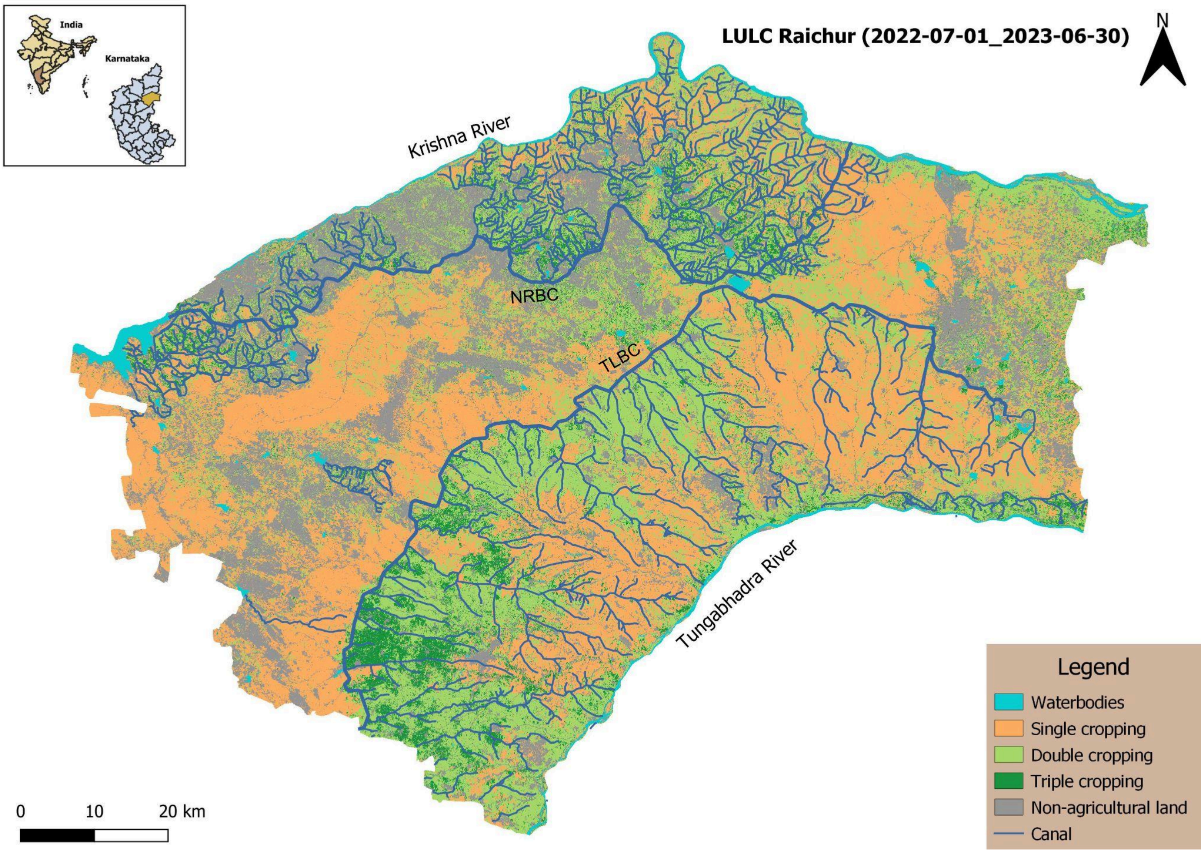

Figure 12: Canal networks and land use land cover in Raichur district

Despite the potential for farmers to earn 2-5 times more net income with 30-50% less water through crop diversification (Chhatre et al., 2016), current irrigation systems force them to grow paddy.

Farmers could cultivate two high-value horticulture crops if water were delivered in a more organised manner. However, those in canal command areas often find it difficult to shift to diversified cropping systems due to flood irrigation and seepage and leakage from earthen field irrigation canals and neighbouring paddy fields.

2.2 Water-Intensive Paddy Monocropping and Land Degradation

While irrigation projects have led to increased water availability and agricultural intensification (Bainda & Malhotra, 2021), they have also had negative environmental impacts.

These include waterlogging, soil degradation, and reduced land fertility (Rizvi, 2012; Pingali & Rosegrant, 1994). The shift towards intensive monocropping, particularly of rice, has caused environmental degradation, increased pest infestations, and soil nutrient depletion (Pingali & Rosegrant, 1994).

Additionally, intensive paddy cultivation under canal irrigation systems is associated with increased reliance on chemical fertilisers and pesticides to maintain high yields, as nutrient depletion and pest pressures rise with repeated monocropping (Tilman et al., 2002). This shift not only affects soil health and biodiversity, but also contributes to groundwater contamination and other negative environmental impacts (Matson et al., 1997).

In many areas with canal irrigation, improper water management has led to rising water tables and waterlogging-induced salinity.

This has resulted in decreased crop productivity and soil fertility—and even the land becoming barren. Waterlogging and soil salinity issues affect approximately 8.4 million hectares of land in the country (Ritzema et al., 2007). Balakrishnan et al. (2008) estimated that ₹824 million would be required for drainage and reclamation in the Upper Krishna Project in Karnataka, with an expected annual net return of ₹326 million.

Outside the canal command area in Raichur, land degradation is driven by factors such as topsoil erosion, groundwater depletion, and soil salinity.

In Maski taluk alone, over 2,000 acres of agricultural land have been abandoned due to soil salinity, severely impacting farmers' livelihoods (Aryan, 2022). Furthermore, a recent assessment by the Alliance for Reversing Ecosystems Services Threats (AREST) estimates that nearly ten million hectares of agricultural land in peninsular India, supporting around 90 million people, are at risk of degradation.

According to the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), restoring degraded lands is critical to ensure food and water security, improve employment opportunities, promote gender equality, and prevent migration and conflict (IPBES, 2019). Addressing land degradation in Raichur requires a multi-faceted approach, integrating scientific assessments with community-driven restoration efforts, sustainable water management, and climate-resilient agricultural practices (Aryan, 2022). A move away from conventional monoculture to low-input polyculture with water-economical crops like millet and sorghum can benefit both farmers and the ecosystem (Kayatz et al., 2019).

Flood irrigation for paddy cultivation also leads to methane emissions, yet farmers lack incentives to adopt 'climate-smart' practices.

Not only does paddy require more water than crops like pulses, legumes, oilseeds and cotton, it also contributes to anthropogenic global warming due to methane emissions, mainly from the flooding of rice fields. Mitigation policies focus on reducing methane emissions by promoting intermittent flooding.

However, the Environmental Defense Fund and its partners' studies of intermittently flooded rice farms in India reveal that nitrous oxide emissions, a greenhouse gas that persists for a long time in the atmosphere, can be significantly higher compared to continuous flooding (Kritee et al., 2018). Correlations suggest that intensified intermittent flooding may increase nitrous oxide emissions by 30-45 times.

Even though the flooding of paddy fields is a major contributor to greenhouse gas emissions from agriculture, farmers do not change cropping patterns, cultivation practices, or irrigation methods due to a lack of knowledge, economic incentives, and market differentiation. (Gupta et al., 2021).

2.3 The Groundwater Gap

Public irrigation systems are designed independently of groundwater. Farmers primarily rely on private investments to use groundwater.

Outside the canal command area and in the tail-end of the canal system, that is, where canal water never reaches, groundwater is emerging as the primary source of irrigation. In Raichur district, there are many tracts of agricultural land in tail-end villages that are double-cropped (Figure 13). This can be mainly attributed to groundwater sources. This is also the case in Mandalgudda, a village at the tail-end of the Narayanpur Right Bank Canal (Figure 14).

The shift towards private exploitation of groundwater has implications for equity in terms of resource distribution. Farmers no longer consider the common pool nature of groundwater—many presume it to be private property and free riding is common in the absence of an understanding of groundwater boundaries (Arghyam, 2015). These issues can be addressed through participatory irrigation management strategies and institutionalising co-management of water resources.

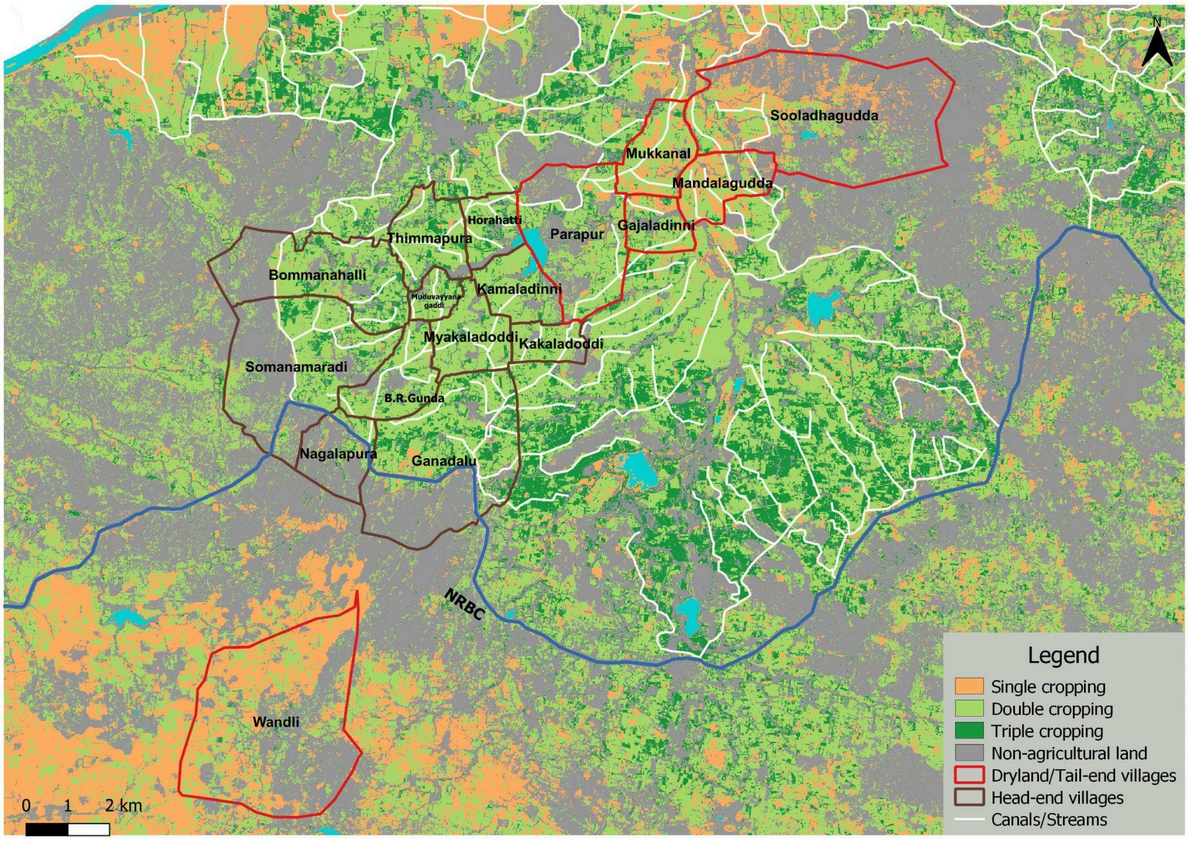

Figure 13: Villages in and outside the Narayanpur Right Bank Canal command area

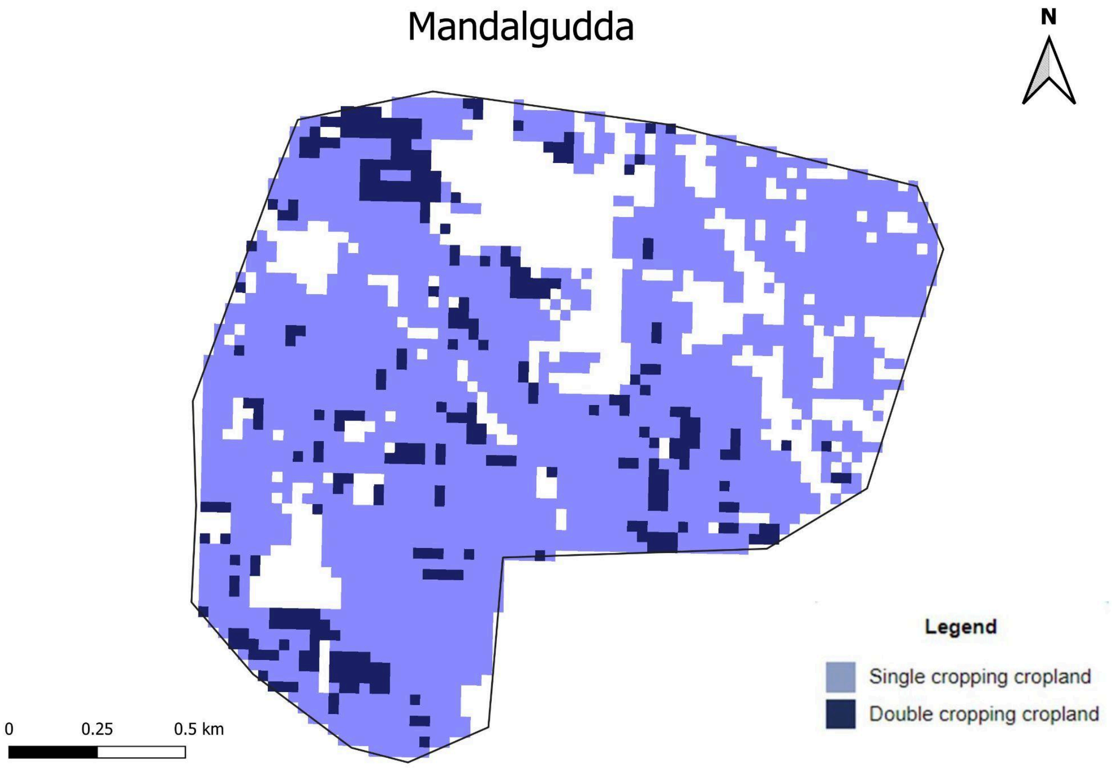

Figure 14: Mandalgudda village land use land cover map, 2022-2023. Source: Indian Institute of Technology Delhi

2.4 Cross-Sectoral Demand for Water

There are escalating demands from urban and industrial sectors on Karnataka's limited water resources.

This is exacerbated by the unequal spatial and temporal distribution of water resources and climate change. The state's water stress is evident in its limited water availability, with approximately 1,072 m^3 per person per year in eastward-flowing rivers (State Water Policy, 2022). Moreover, recurrent droughts and 70% of the annual rainfall occurring in a short window (June to September) further strain water resources.

The agriculture sector in Karnataka also faces challenges such as low cropping intensities[13] (110% to 125%) and irrigation efficiencies[14] (40%) (State Water Policy, 2022). Despite over 84% of state water resources being allocated for agriculture, the gross area irrigated falls short of its potential. Irrigation projects such as the Upper Krishna Project aim to irrigate millions of acres across districts, but only 24.5% of the agricultural land in Raichur is currently irrigated (Vital Capital, 2023). Deficient infrastructure, management constraints, and inadequate promotion of water-saving crops and practices further hinder irrigation efficiency.

Projections indicate a 40% increase in domestic water demand, particularly for industry and household use, from 37 km^3 in 2000 to 52 km^3 in 2025. This surge in demand is expected to reduce the proportion of water allocated to agriculture from 84% in 2000 to 73% by 2025, posing a challenge to sustainable economic growth.

Climate change further puts a strain on water resources. Projections indicate that Raichur may experience a temperature increase of 2°C or more by the 2030s under high-emission scenarios (Indian Institute of Science, 2014). These factors underscore the urgency for sustainable water resource management strategies tailored to the district's unique needs and challenges.

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[13] Cropping intensity is calculated as the ratio between net sown area and gross cropped area. The minimum cropping intensity for a plot of farmland is 100% and the maximum is 300%, which accounts for cultivation carried out over three seasons: *kharif, rabi and zaid.* A range of 110 to 125% implies that most farmers grow a single crop in a year, which fetches lower income than double or triple cropping.

[14] The term irrigation efficiency is used to express which percentage of irrigation water is used efficiently and which percentage is lost.

2.5 Climate Impacts

Extreme climate events further compound the challenges discussed above.

Increasing climate variability and extreme weather events such as droughts and floods, result not only in direct crop losses, but also in false starts—the loss of seeds due to premature sowing is a common phenomenon. These increase already high farming costs and make farmers susceptible to debt cycles.

Studies on climate change in Karnataka reveal a persistent warming trend and decline in rainfall (State Water Policy, 2022). This shift is expected to increase the number of regions affected by droughts. During the kharif season, northern districts are anticipated to experience a 10-80% rise in drought occurrences, with some areas potentially seeing a near doubling in frequency. Additionally, floods are becoming more frequent due to intense rainfall, which can exceed the long-term average by 10 to 20 times on certain days.

3. Socioeconomic Challenges in Agriculture

In this section, we detail some of the socioeconomic trends or drivers of change in India's agrarian sector, particularly in resource-stressed regions like the Raichur Transformation Lab.

1. There is fragmentation of agricultural landholdings and agriculture is becoming economically unviable.

The size of landholdings has been consistently shrinking with every generation, predominantly due to inheritance laws. Small and marginal landholdings taken together (0.00-2.00 ha) constituted 86% of total landholdings in 2015-16 (Government of India, 2019). The all-India average size of a landholding is 1.08 ha. (Press Information Bureau, 2020). As a result of small land sizes, cultivators are pushed towards informal wage labour. Compared to 2001, India recorded nearly 40 million more agricultural workers in 2011[15] and around 9 million fewer cultivators.[16]

This trend reflects the increasing unviability of agriculture for small and marginal households. According to the Government of India's Committee on Doubling of Farmers' Income, 2018, a member of an agricultural household earned around ₹214 a month, but the expenditure was about ₹207 a month (Mahapatra, 2019). This leaves a disposable income of just ₹7 a month.

The share of household income from farming has decreased from 3/4th of the total household income in 1970 to 1/3rd in 2015. Even as the monthly income of agricultural households increased between 2012-13 and 2018-19, income from cultivation went down from 48% to 38%. Wages and income from livestock contributed more to the income.

Historically, developed economies have seen increased per capita incomes as labour shifted from agriculture to formal non-farm sectors, leading to economic formalisation. However, recent studies in India suggest that farmers are abandoning agriculture due to distress rather than formalisation (Basole & Basu, 2011a, 2011b; Basole, 2022). With over half of India's population relying on

[15] A person who works on another person's land for wages in money or kind or share is regarded as an agricultural labourer. She or he has no risk in the cultivation, but merely works on another person's land for wages.
[16] "A person is classified as cultivator if he or she is engaged in cultivation of land owned or held from Government or held from private persons or institutions for payment in money, kind or share.

agriculture, mainly small and marginal farmers, distress is evident in rising debt-to-asset ratios and millions transitioning to agricultural labour.

2. There is uncertainty and stagnation in agricultural incomes.

Agricultural incomes are uncertain because of monsoon patterns, increasing land degradation, and market price fluctuations. In Mukkanal village of Raichur district, the yield per acre of pearl millet in degraded agricultural land is 5 quintals compared to 10 quintals in fertile lands. To fight yield reduction, farmers use chemical inputs excessively, which increases the cultivation cost.

Economist Jean Dreze recently analysed the growth in real wages (that is, factoring in inflation) in India. Between 2014 and 2021, labourers' real wages increased by less than 1% across agriculture, construction, and non-agricultural sectors. During this time, the average consumer price inflation stood at 6%. This means that the ability of the poor to save and spend on improving their quality of life remains severely hampered (Dreze, 2023).

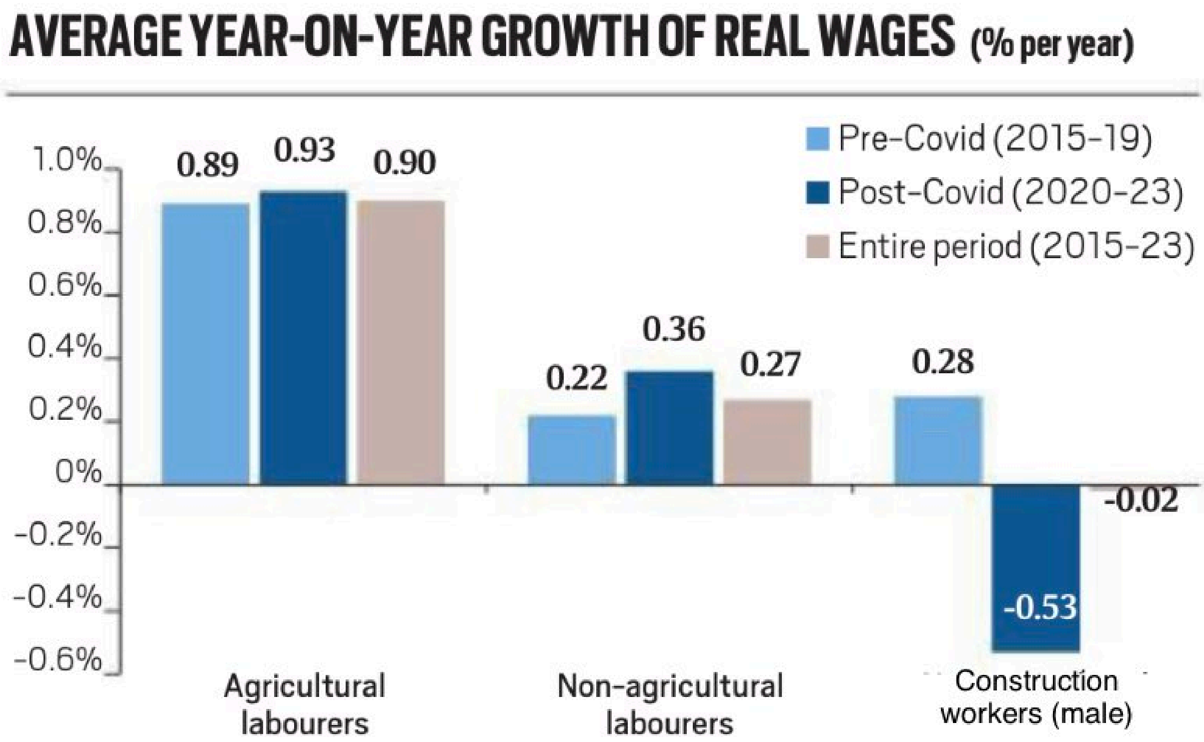

Figure 15: Average year-on-year growth of real wages. Source: Dreze, 2023

4. The ad hoc use of fertilisers and pesticides results in rising input costs and debt traps.

WELL Labs' journey mapping exercise in Raichur (unpublished) shows that for every ₹100 spent by the farmer on cultivation, approximately ₹66 is spent on industrially produced inputs. The excessive use of chemical fertilisers and pesticides also increases soil salinity and degradation, resulting in a vicious cycle that further increases the risk involved in agriculture and lands farmers in debt traps.

The decline in farmer incomes and biophysical degradation is not coincidental. Rather, it points to the fact that monocropping farming systems with the intensive use of industrially produced inputs inevitably lead to land degradation and reduced yields over the long term. This trend coincides with a shift towards non-food crops in cropping patterns, a substantial increase in privately owned tubewells, and the privatisation of agricultural inputs like seeds and fertilisers (Sarkar & Das, 2014). The increasing reliance on pesticides and fertilisers to maintain yields makes farmers susceptible to their escalating costs, which are determined by intricate global supply chains and fossil fuel prices (Bera, 2022).

5. Smallholder farmers across rural India are migrating to towns and cities to find better jobs and wages.

WELL Labs' aspirations study (unpublished) conducted in Mukkanal, Mundargi and Chadakalgudda villages in Raichur district shows that almost 70% of households have a family member migrating for work either permanently or seasonally. Seasonal migration (more often than not, of men) has resulted in the feminisation of agriculture—women spend more time in fields and take up much of the drudgery and day-to-day tasks associated with agriculture (Varsha et al., 2025). Women comprise nearly 30% of total cultivators and 41% of agricultural labourers (Government of India, 2019).

Nearly 42% of rural households are landless (Kishore, 2015). On the other hand, permanent migration for livelihood reasons has led to farmers abandoning their lands. Private companies purchase these lands or take them up on long-term leases for non-agricultural purposes, such as solar projects. As a result, many farmers who previously owned land become landless.

6. Policies and subsidies for the sector incentivise unsustainable cultivation methods.

Since the Green Revolution[17], India has implemented a subsidy regime to incentivise agricultural production and ensure food security. While these subsidies have helped boost yields, they have also inadvertently encouraged unsustainable cultivation practices, such as excessive groundwater extraction, monocropping, and intensive fertiliser and pesticide use (Chatterjee et al., 2022).

The budgetary support for the sector is allocated majorly through the following:

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[17] The Green Revolution refers to "a series of research, development, and technology transfer initiatives, occurring between 1943 and the late 1970s in, which increased industrialised agriculture production in many developing nations. The initiatives involved the development of high-yielding cereal grains, expansion of irrigation infrastructure, and distribution of hybridised seeds, synthetic fertilisers, and pesticides to farmers."

a. Procurement and Minimum Price Support (MSP)

The government provides an output subsidy by procuring major crops at a Minimum Support Price (MSP). This ensures price stability for farmers. However, the MSP regime disproportionately favours crops like paddy and wheat, leading to monocropping, reduced crop diversity, and inefficient water use. This discourages the adoption of more sustainable, drought-resistant, or regionally appropriate cropping patterns.

b. Stock Subsidy

The government maintains large-scale buffer stocks of crops such as wheat and rice. While these reserves enhance food security, they also influence cropping choices, often incentivising cultivation beyond regional agro-climatic suitability.

c. Fiscal Subsidies to States

The Government of India compensates states for taxes and fees levied on agricultural produce, indirectly supporting market inefficiencies and price distortions, which can lead to over-reliance on specific crops.

d. Fertiliser Subsidy

With a budget allocation of ₹1.67 trillion for industrially produced fertilisers, particularly urea, this subsidy promotes excessive and imbalanced fertiliser application, degrading soil health and contributing to nitrogen pollution.

In contrast, there is no dedicated subsidy for ‘natural’ or organic inputs, despite plans to establish 10,000 bio-input centres over five years with a ₹1 billion budget. The lack of financial incentives for sustainable alternatives further entrenches the use of industrially produced fertilisers and pesticides in farming.

e. Direct Income Support

Under government schemes like PM Kisan[18] and Pradhan Mantri Fasal Bima Yojana (PMFBY)[19], direct income benefits or cash transfers are provided to agricultural households, averaging ₹18,000 to ₹20,000 annually per household. However, accessibility issues and the actual impact on long-term agricultural sustainability remain concerns (Chatterjee et al., 2022; Press Information Bureau, 2022).

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[18] PM Kisan, also known as Pradhan Mantri Kisan Samman Nidhi, provides income support of ₹6,000 per year to all landholding farmer families.

[19] The Pradhan Mantri Fasal Bima Yojana (PMFBY) is a crop insurance scheme that seeks to provide financial protection to farmers against crop loss due to natural disasters (hail, drought, famine), pests, and diseases.

f. Electricity Subsidy

The provision of free or highly subsidised electricity to pump groundwater for irrigation has significantly contributed to unsustainable groundwater extraction. With little financial incentive to conserve water, farmers overuse electric-powered borewells, leading to rapid groundwater depletion. This has exacerbated water stress in arid and semi-arid regions, increasing dependency on deeper borewells and making irrigation costlier in the long run.

While these subsidies support farmers, they also reinforce unsustainable agricultural practices. Addressing these challenges requires rethinking subsidy structures to promote resource-efficient and climate-resilient farming methods, such as diversified cropping systems, the use of organic inputs, and efficient irrigation techniques.

4. Stakeholders in the Raichur Transformation Lab

WELL Labs conducted a stakeholder mapping exercise in Devadurga taluk in Raichur to identify the community the research addresses and key actors at the local and state levels. The stakeholders in the Raichur Transformation Lab are as follows:

4.1 Farmers

The National Commission of Farmers defines a farmer as "a person actively engaged in the economic and/or livelihood activity of growing crops and producing other primary agricultural commodities. It includes agricultural operational holders, cultivators, agricultural labourers, sharecroppers, tenants, poultry and livestock rearers, fishers, beekeepers, gardeners, pastoralists, non-corporate planters and planting labourers, as well as persons engaged in various farming-related occupations such as sericulture, vermiculture and agro-forestry. The term also includes tribal families/persons engaged in shifting cultivation and in the collection, use, and sale of minor and non-timber forest produce."

According to this definition, around 54.6% of the Indian workforce depends on agriculture and allied activities (Ministry of Finance, 2021). Small and marginal farmers own 83% of landholdings (Agriculture Census of India, 2015-16). In the Raichur Transformation Lab, farmers include the following sub-groups:

4.1.1 Cultivators

A person is classified as a cultivator if "he or she is engaged in the cultivation of land owned or held from Government or held from private persons or institutions for payment in money, kind or share". It includes both full-time and part-time farmers who cultivate crops.

4.1.2 Agriculture Labourers

A person is classified as an agricultural labourer if they work on another person's land for wages in money, kind, or share. Their primary source of income is wage labour from agriculture and other land management activities including, projects under the Mahatma Gandhi National Rural Employment Guarantee Act[20]. Apart from the landless, this group could also overlap with cultivators, especially small and marginal farmers, whose dependence on wage labour is increasing. The share of agricultural labourers in the workforce increased from 40% in 1991 to 55%

[20] Enacted in 2005, the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is the world's largest employment programme. It aims to enhance livelihood security in rural areas by guaranteeing at least 100 days of wage employment in a financial year to every household.

in 2011. Thus, there are now more labourers than cultivators (Government of India, 2019).

4.1.3 Livestock Owners

This includes individuals who own livestock and use land for grazing or fodder. The Raichur region has a livestock-rearing community that travels across districts and states to search for grazing lands and water. They cultivate a symbiotic relationship with landowners, who allow grazing in harvested fields. The consequent manure deposition improves soil fertility. Apart from the livestock rearing community, landholders and agriculture labourers also usually have livestock herds, especially small ruminants like goats or sheep.

4.1.4 Farmer Collectives

This includes water-user cooperative societies, labour groups, self-help groups, and microenterprises. Farmers and agricultural labourers set up different kinds of collectives depending on their goals.

Water-user cooperative societies are supposed to be established for every 500 hectares of irrigated canal command area, but they are mostly non-existent. Local NGOs like Prarambha are trying to mobilise them by federating farmer self-help groups around field irrigation channels.

This website lists some of the major farmer producer organisations in Raichur district.

4.2 Nonprofits

This includes natural resources management, rural development, and community mobilisation organisations. NGOs can act as an extension of the community and play a crucial role in mobilising communities, forming water-user associations, and facilitating water-sharing agreements.

Some of the nonprofits working in the region are Prarambha, SOIL Trust, BAIF Development Research Foundation, Foundation for Ecological Security, PRADAN, ISAP India Foundation, Grameena Mahila Abhirudhi Shikshana Samsthe (GRAMS), Sajjalashri Integrated Studies On Agriculture And Rural Development Society, SELCO Foundation, and India Foundation for Humanistic Development (IFHD).

4.3 Government Departments

This includes state and local government functionaries, especially those working in institutions under the Water Resources Department, Government of Karnataka.

The **Command Area Development Authority (CADA)** is responsible for mobilising communities, setting up water-user cooperative societies, and establishing water-sharing arrangements.

Various **Jala Nigams**[21], each for different irrigation projects, manage water distribution in the command area.

The **Water and Land Management Institute (WALMI)** is responsible for training farmers and water-user cooperative society functionaries.

The **Advanced Centre for Integrated Water Resources Management (ACIWRM)** is a think tank under the Water Resources Department that enables policy decisions to increase water productivity and equity with the help of data, research, and technology. ACIWRM has multiple research and implementation projects in Raichur to monitor water-use efficiency and productivity. It also conducts farmer water schools to promote the adoption of water-efficient cultivation practices.

Local self-government institutions[22] like gram panchayats are important nodes to coordinate and implement water management initiatives.

4.4 Market Players

Market players are crucial stakeholders to ensure consistent markets and fair prices for sustainable agricultural produce. These are some of the market players promoting sustainable agriculture in the region:

1. **Safe Harvest**: It procures staples and cereals cultivated through non-pesticide management, that is, without using conventional or synthetic pesticides.
2. **Udaanta Trust**: It promotes and procures Kandu, an indigenous brown-coloured cotton variety, as an alternative to BT cotton[23].
3. **Janara Samuha Mutual Benefit Trust (JSMBT):** A federated community organisation launched and run by Prarambha, it acts as an intermediary between farmers and market players like Safe Harvest and Udaanta.

[21] Jala Nigams are organisations set up for the implementation of irrigation projects in Karnataka. They include Krishna Bhagya Jala Nigam Limited (KBJNL), Karnataka Neeravari Nigama Limited (KNNL), Visvesvaraya Jala Nigama Limited (VJNL), and Cauvery Neeravari Nigam Limited (CNNL).
[22] The Constitution (73rd Amendment) Act, 1992 and Constitution (74th Amendment) Act, 1992 devolved powers and functions to panchayati raj institutions to promote local self-governance in India. It consists of a tiered system: gram panchayat at the village level; taluk panchayat at the taluk level; and zilla panchayat at the district level.
[23] BT cotton is a genetically modified variety of cotton.

4.5 Research Institutes and Knowledge Partners

WELL Labs is collaborating with various organisations and projects for research and pilot projects in the Raichur Transformation Lab. **Climate Adaptation and Resilience in Tropical Drylands (CLARITY)** is a critical partner in establishing the Raichur Transformation Lab and developing a holistic approach to rural research and transformation.

WELL Labs is working with the **Indian Institute of Technology Delhi** to generate land use land cover maps and other GIS-based research outputs for the Transformation Lab.

We have also partnered with the **Ashoka Trust for Research in Ecology and Environment (ATREE)** and **Sustainable and Healthy Food Systems (SHEFS)** initiative to develop a farm-scale trade-off assessment tool.

Another partner is the **IHE Delft Institute for Water Education**, located in Delft, Netherlands. We are working with them to leverage remote sensing for the equitable distribution of irrigation water.

There are other research institutes working in the region or collaborating with organisations there. The **University of Agriculture Sciences, Raichur** is an important Indian Council for Agriculture Research (ICAR)-backed research institution influencing farmer decisions on seed variants, soil improvement, and nutrients. However, it has limited reach.

4.6 Other Partners

DCB Bank and NVIDIA are supporting Prarambha and WELL Labs' initiatives to restore degraded agricultural land, improve water access, and promote sustainable farming in Karnataka's Raichur and Koppal districts.

WELL Labs is working with DCB Bank to promote regenerative agriculture, protective irrigation, and soil restoration through techniques like green manuring and Akkadi Saalu, alongside farmer training and government engagement to mobilise public financing.

The NVIDIA-backed initiative helps farmers transition from monocultures and the intensive use of industrially produced fertilisers and pesticides to a diversified cropping system with non-pesticide management, protective irrigation, and community-led water governance through water-user associations.

Both projects integrate traditional practices with technologies such as GIS-based water mapping and remote sensing to enhance land and water productivity, increase farmer incomes, and build climate resilience.

5. Initiatives to Co-Create Knowledge with Stakeholders

Knowledge production under this project involves collaborative efforts among various stakeholders to generate actionable insights. These include:

Journey Mapping

We worked with farmers to understand material flows, finance flows, and information flows during the cropping season. The exercise also involved quantitative and qualitative analyses to understand socioeconomic conditions and historical perspectives, with a focus on cropping patterns.

Aspirations Study

We conducted the study with around 200 farmers in three villages to document the aspirations of farming households.

Scenario Modelling and Tools

We modelled multiple farm-scale scenarios to estimate net farmer income, water demand, fodder availability, fodder requirement, manure availability, and carbon sequestration for different farming choices. A land use land cover map-based Excel tool was developed to aggregate farm choices at the distributary scale.

Community Visioning Workshops

We conducted visioning workshops with farmers of two field irrigation channels under Lateral 1A, Distributary 10, Narayanpur Right Bank Canal to understand the barriers to diversified cropping systems. Currently, monoculture paddy is prevalent, especially at the head end of the canal.

Stakeholder Roundtables

In March 2023, WELL Labs and the India Climate Collaborative convened a roundtable with key stakeholders working in the Raichur Transformation Lab to explore successful models for equitable water sharing, identify bottlenecks in scaling up those models, and foster collaborations around protective irrigation. Stakeholders representing government, civil society organisations, philanthropic organisations, Corporate Social Responsibility departments, market players, and researchers participated in the roundtable.

Insights from the above exercises are incorporated in this report.

6. Pathways to Better Water Management and Sustainable Agriculture

Effective water management and sustainable agriculture in Raichur require a multi-stakeholder approach, involving panchayats, civil society organisations, government agencies, water-user cooperative societies, farmer groups, research institutions, and private sector partners.

While canal command areas face challenges related to inequitable water distribution, last-mile delivery issues, and waterlogging, regions outside the canal command area struggle with groundwater depletion, soil salinity, and erratic rainfall. Addressing these challenges requires a comprehensive support system integrating water governance, infrastructure, sustainable inputs, decentralised water-sharing mechanisms, improved market access, and service-driven entrepreneurship models to ensure long-term agricultural resilience.

We discuss some of these pathways to better water management and sustainable agriculture in the Raichur Transformation Lab below:

1. Strengthen water-user cooperative societies through multi-stakeholder engagement.

The Narayanpur Left Bank Canal has 3,800 of these societies, most of which remain inactive. Panchayats and civil society organisations can play a crucial role in reviving these institutions and extending participatory water management to non-canal areas, linking them to community-led initiatives such as seed banks, bio-resource input centres, and farmer-led water governance models.

2. Water governance and last-mile infrastructure improvements are key for equitable water distribution.

In canal command areas, investing in last-mile irrigation infrastructure—such as field channels, water storage structures, and micro-irrigation systems—can improve access for tail-end farmers and reduce water wastage. Implementing water budgeting-based crop planning can help optimise irrigation schedules and match water allocation with crop needs, thereby preventing excessive withdrawal and ensuring efficient use.

Outside canal command areas, water-sharing mechanisms such as borewell pooling, tank-filling schemes, and lift irrigation can help reduce groundwater overexploitation and ensure its equitable distribution among smallholder farmers.

3. Innovation and lowering costs are important as current canal automation systems are expensive.

While full-scale canal automation is costly, demand-side solutions such as community-controlled water distribution, strengthening last-mile irrigation infrastructure, groundwater recharge structures, and decentralised lift irrigation systems can improve water-use efficiency.

4. Farmer-support systems can aid in sustainable transitions.

a. Water budgeting and crop planning: Both canal and non-canal areas require water budgeting-based crop planning to balance water availability with crop choices.

b. Bio-resource input centres: These are local hubs providing bio-fertilisers, composting solutions, and biological pest control inputs to reduce farmers' dependence on industrially produced fertilisers and pesticides.

c. Village seed banks: Community-managed seed banks ensure access to regionally adapted, climate-resilient crop varieties and reduce their reliance on external seed markets.

d. Custom hiring centres for farm mechanisation and irrigation support: Farmers often lack access to affordable labour-saving technologies, particularly for diversified cropping systems. Custom hiring centres can provide rental services for tractors, electric weeders, seed drills, transplanters, and irrigation pumps, reducing labour costs and promoting efficient resource use.

e. Community hydrologists: Training local youth to become community hydrologists—skilled in groundwater monitoring, soil moisture assessment, and participatory water governance—can support decentralised decision-making and help villages manage water resources more effectively.

f. Entrepreneurial service models: Farmers and rural youth can be trained to operate bio-input centres, seed banks, and water-sharing services, creating sustainable livelihoods while providing essential services.

5. Invest in drainage and soil health to mitigate waterlogging and salinity.

In canal command areas, poor drainage leads to waterlogging and salinity. Outside the canal command area, soil moisture conservation techniques such as farm ponds, check dams, and agroforestry can enhance productivity and soil resilience.

6. Farmers are willing to pay for reliable water access if systems are efficient.

Farmers in non-canal areas can benefit from small-scale irrigation schemes using shared borewells, lift irrigation from tanks, and check dams, which provide critical water access during dry periods. In canal command areas, well-managed and strengthened water-user cooperative societies can facilitate water pricing models for equitable access, ensuring tail-end farmers receive their fair share of water.

7. Market access is key to encouraging crop diversification.

Farmers continue growing paddy due to assured markets and a guaranteed minimum support price, while crops like millets, pulses, and oilseeds lack organised procurement. Panchayats, farmer producer organisations, and private sector players must collaborate to develop aggregation models and processing units, and secure procurement contracts for other crops.

8. Donor education must focus on facilitation and long-term engagement.

Infrastructure investments alone will not drive sustainable transitions. Funding must also support capacity building, entrepreneurship training, and sustained farmer engagement to ensure long-term resilience.

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A. Annexure

This section lists publications on agriculture by WELL Labs and its partners.

A.1 Research

1. Policy Brief: Augmenting Farmer Income With On-farm Carbon and Water Trade-offs
2. Addressing the Labour Barrier in the Transition to Crop Diversification

A.2 Media Articles and Blogs

1. Diversifying Income Sources to Incentivise Smallholder Farmers
2. Envisioning an Equitable Transition to Regenerative Agriculture Using a 'Ladder' Approach
3. Restoring Landscapes and Improving Farmer Incomes, the People-Centric Way
4. Field Notes from Sittilingi Valley: How a Farmer Collective Addresses Both Healthcare & Agrarian Distress
5. A Package of Practices for Climate-Smart Agriculture
6. The World Beneath Our Feet, Why Soil Biodiversity is Vital for Ecological Restoration
7. [Commentary] Is agroecological farming a solution for rainfed degraded land?
8. From Plural Livelihood to Schools: What people aspire for in Raichur
9. Part 1: Mapping the Future of Mukkanal's Farmers
10. Part 2: 5 Insights from Journey Mapping in Mukkannal
11. Restoring Raichur's Degraded Land: How we studied the local context.
12. Stakeholder Mapping: A Key Step for Restoration of Degraded Lands
13. Soil Workshop in Raichur: Farmers Keen to Try New Methods to Rebuild Soils
14. A Package of Practices for Climate-Smart Agriculture
15. Explainer: How Green Manure Can Help Degraded Farmlands Sustain Themselves
16. Pots Show the Way: A 2,000 year old irrigation system is being revived in north Karnataka
17. Feeding humans has trapped the world in debt, degradation: FAO report
18. Article on impact of NREGA TCBs on soil and moisture conservation

Glossary

Agricultural labourer	A person who works on another person's land for wages in money, kind, or share. See the complete definition here.
Aspirational district	The Aspirational Districts Programme seeks to "quickly and effectively transform the 112 most under-developed districts across the country".
Cropping intensity	Cropping intensity is calculated as the ratio between net sown area and gross cropped area. The minimum cropping intensity for a plot of farmland is 100% and the maximum is 300%, which accounts for cultivation carried out over three seasons: *kharif, rabi and zaid*. A range of 110 to 125% implies that most farmers grow a single crop in a year, which fetches lower income than double or triple cropping.
Cultivator	A cultivator is engaged in the cultivation of land owned, held from the government, or held from private persons or institutions for payment in money, kind, or share. See the complete definition here.
District	A district is an administrative subdivision of a state in India. It comprises several taluks (see below).
Doab	Doab refers to the land lying between two confluent rivers.
Drylands	Drylands are characterised by a scarcity of water. Their soils tend to be vulnerable to wind and water erosion, subject to intensive mineral weathering, and of low fertility (due to the low content of organic matter in the topsoil). Drylands are found in most of the world's biomes and climatic zones and constitute 41% of the global land area.
Financial year (FY)	The financial year in India begins on 1 April and ends on 31 October.
Green Revolution	The Green Revolution refers to "a series of research, development, and technology transfer initiatives, occurring between 1943 and the late 1970s in, which increased industrialised agriculture production in many developing nations. The initiatives involved the development of high-yielding cereal grains, expansion of irrigation infrastructure, and distribution of hybridised seeds, synthetic fertilisers, and pesticides to farmers."
Irrigation efficiency	The term irrigation efficiency is used to express which percentage of irrigation water is used efficiently and which percentage is lost.

Jala Nigam	Jala Nigams are organisations set up for the implementation of irrigation projects in Karnataka. They include Krishna Bhagya Jala Nigam Limited (KBJNL), Karnataka Neeravari Nigama Limited (KNNL), Visvesvaraya Jala Nigama Limited (VJNL), and Cauvery Neeravari Nigam Limited (CNNL).
mbgl	Metres below ground level
Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA)	Enacted in 2005, the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) is the world's largest employment programme. It aims to enhance livelihood security in rural areas by guaranteeing at least 100 days of wage employment in a financial year to every household.
Minimum support price (MSP)	A price set by the government at which it purchases a certain crop from farmers. An MSP ensures that farmers do not suffer losses due to market fluctuations. Only some crops have MSPs, prompting farmers to grow them more.
NABARD	The National Bank for Agriculture and Rural Development (NABARD) is India's apex development bank, established in 1982 under an Act of Parliament to promote sustainable and equitable agriculture and rural development.
NITI Aayog	A Government of India policy think tank
PM Kisan	PM Kisan, also known as Pradhan Mantri Kisan Samman Nidhi, provides income support of ₹6,000 per year to all landholding farmer families.
Pradhan Mantri Fasal Bima Yojana (PMFBY)	The Pradhan Mantri Fasal Bima Yojana (PMFBY) is a crop insurance scheme that seeks to provide financial protection to farmers against crop loss due to natural disasters (hail, drought, famine), pests, and diseases.
Protective irrigation	Protective irrigation systems are "designed and operated on the principle that the available water in rivers or reservoirs has to be spread thinly over a large area, in an equitable manner. The idea is to reach as many farmers as possible, and to protect them against crop failure and famine, which would regularly occur without irrigation in regions with low and erratic rainfall."
Scheduled Caste	The Constitution of India has designated certain marginalised castes as Scheduled Caste. The Government of India and states have affirmative action policies to benefit these groups

Scheduled Tribe	The Constitution of India has designated certain indigenous communities as Scheduled Caste. The Government of India and states have affirmative action policies to benefit these communities.
Self-help group	A self-help group is a community-based microfinance group, usually comprising women, where members provide financial and other kinds of support to each other to start new businesses or income-generating activities.
Taluk	A taluk or taluka is an administrative subdivision of a district for revenue purposes. It comprises several villages.
Under water table conditions	The US Geological Survey explains under water table conditions as follows: "Groundwater in aquifers between layers of poorly permeable rock, such as clay or shale, may be confined under pressure. If such a confined aquifer is tapped by a well, water will rise above the top of the aquifer and may even flow from the well onto the land surface. Water confined in this way is said to be under artesian pressure, and the aquifer is called an artesian aquifer... Where groundwater is not confined under pressure, it is described as being under water table conditions... Water-table aquifers generally are recharged locally, and water tables in shallow aquifers may fluctuate up and down directly in unison with precipitation or streamflow."