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Assessing Groundwater Availability and Agricultural Productivity in Guntur District, Andhra Pradesh

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HIGHLIGHTS

- Groundwater is central to sustaining agriculture in Guntur district.
- Guntur remains productive, but local groundwater stress is emerging in some areas.
- Sustainable agriculture will require better irrigation, recharge, and crop planning.

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ABSTRACT

The availability of groundwater in semi-arid areas of India is decisive to agricultural production, although it can be easily evaluated independently of crop structure, irrigation sources, and hydrological stress at the district level. The paper will provide a synthesized secondary-based data analysis of the groundwater availability and agricultural productivity in the undivided Guntur district within the state of Andhra Pradesh. The district has an average rainfall of approximately 853 mm annually and a cropping intensity of 134.6 therefore indicating a very productive yet a water sensitive agrarian system. Although the estimates of the groundwater resources in the district scale surface suggest an extensive net dynamic availability, results in the pre-monsoon groundwater levels and the localized overexploited areas indicate the emergence of stress in the individual mandals. The concentration of crop in paddy, cotton, pulses and maize, coupled with the presence of canal water and ground water irrigation, demonstrates that agricultural output does not only hinge on the overall amount of water but also on the spatial dependability, accessibility during a specific season and irrigation control. The paper suggests that the future of agricultural sustainability in Guntur will be based on conjunctive water utilization, focused recharge, micro-irrigation, groundwater surveillance, as well as a progressive transition in stressful regions to agricultural crop options with high water consumption.

1. INTRODUCTION

The groundwater has grown to be one of the greatest sources of agricultural development in India. It has allowed irrigation expansion, more farming intensity, and insurance of farmers against variation in rainfall; conversely, excessive extraction has generated significant sustainability issues in most

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areas (Shah, 2009; Rodell et al., 2009; Dangar et al., 2021). The evidence on this matter is that depletion of groundwater is not just a hydrogeological problem anymore. It is directly related to the food security, profitability of farms, the adaptation to climate variability, and regional disparities in the agricultural performance (Aeschbach-Hertig and Gleeson, 2012; Fishman, 2018; Jain et al., 2021). District-level measurements are also of particular significance since the state of groundwater is spatially dissimilar. Aggregate state or national data may conceal local variations in the behavior of the aquifers, irrigation networks, crop selections, and how much of the canal water, rainfall, or wells may be replaced by farmers. The Andhra Pradesh district of Guntur is a convenient example of such assessment due to the combination of deltaic fields, canal irrigation, areas reliant on the use of borewells, commercial crop fields, and the repetitive problems with the stress on groundwater, as well as water-use efficiency. Secondly, the district has been regarded as a major agricultural area since ancient times with the intensive production of paddy, cotton, pulses, maize, chillies, and other high value crops (ICAR-CRIDA). The available information on Guntur is distributed in bits in the form of district contingency reports, groundwater evaluations and crop statistics. The only thing lacking is usually a single analytical story that puts groundwater availability, irrigation structure, concentration of crops and agricultural productivity in the same context. This gap is met in the given paper by synthesizing secondary sources. Instead of estimating production functions at farm level, it assesses the structural relation of ground water conditions and agricultural productivity at the district level.

The research objectives are to: (i) define the agro-hydrological profile of the Guntur district; (ii) determine the level of groundwater availability and local stresses; (iii) determine the cropping and irrigation arrangement of the district in relation to the agricultural productivity; (iv) and find out policy priorities in order to sustain agricultural output without groundwater increasing vulnerability.

2. STUDY AREA AND DATA COLLECTION

This evaluation is based on the undivided district of Guntur structure of the district level source materials. That set up sees Guntur occupying an area of approximately 11391 sq km and receiving a yearly average of approximately 853 mm of precipitation. It consists of a combination of black cotton soils, red soils, coastal sandy soils, and a minor portion of alluvial soils. Black cotton soils occupy the greatest proportion of the area according to the district contingency profile, which is why it is possible to understand the importance of the district in terms of both cereal and commercial crop production (ICAR-CRIDA).

It is a literature-based study that is solely based on secondary data. The main sources are the following: (a) the ICAR-CRIDA district agriculture contingency plan of Guntur with the information about the rainfall, land use, crop area, irrigation, and productivity; (b) CGWB NAQUIM report of Guntur district, the information about groundwater resource status and observation with aquifer; (c) CGWB Ground Water Year Book 2021-22 with Andhra Pradesh, information about the groundwater level seasonally; (d) the peer-reviewed literature focused on groundwater depletion, ground

Since the administrative limits in Andhra Pradesh have evolved with time, the statistics recorded in this context must be understood to suggest the undivided district context, in which the source reports have been compiled.

3. MATERIALS AND METHODS

The paper relies on the triangulation of official reports and published research as the descriptive analytical design. Three steps of the analysis were applied. The first step involved the compilation of agro-hydrological baseline indicators, such as rainfall, net sown area, gross cropped area, cropping intensity, irrigated area and the status of ground water resource. Secondly, crop concentration and source irrigation structure were analyzed to know how the production system of the district is determined by water availability. Third, the interpretation of groundwater conditions implications on the agricultural productivity was considered regarding the district-level crop productivity data and the country literature on agriculture that is dependent on groundwater. This is not econometric yield-response research or a farm-household survey. In this respect, therefore, the paper does not purport to make a causal estimate of the number of units of crop output that respond to a unit change in groundwater depth. Rather, it evaluates the structurality of relationships: where crop dependences on irrigation are clumped, where groundwater pressures are already manifesting themselves and how the predictability of water availability is set to affect agricultural activity. This strategy is suitable in the interpretation of the policy at a district level but it is less effective than the causal analysis at the plot level. Figures were also recreated based on the authoritative district-level numbers in order to be clearer and tables were rearranged to reveal the most policy-to-be-considered indicators in a form of submission.

4. RESULTS AND DISCUSSION

4.1 Agro-hydrological profile of the district

The base indicators prove that Guntur is a highly agricultural-based district and heavily relies on controlled access to water. Net sown area is approximately 597.0 thousand ha and gross cropped area is 803.6 thousand ha which generates a cropping intensity of 134.6%. The net irrigated land area is 373.6 thousand ha with 223.4 thousand ha of rainfed area. This framework implies that agricultural economy of the district is influenced by a blend of irrigation guarantee and leftover rainfall hazard. Practically such a system may be able to sustain high output; however, it is very susceptible to variation in the reliability of canals, the availability of groundwater and monsoon performance (ICAR-CRIDA).

Table 1. Selected agro-hydrological indicators of Guntur district

Indicator	Value	Interpretive relevance
Geographical area	1,139.1 thousand ha	Large agricultural district under the undivided administrative boundary
Average annual rainfall	853 mm	Moderate rainfall, but seasonal variability still creates irrigation dependence
Net sown area	597.0 thousand ha	Indicates broad agricultural base
Gross cropped area	803.6 thousand ha	Reflects multiple cropping and production intensity
Cropping intensity	134.6%	Signals high dependence on reliable water for repeat cropping
Net irrigated area	373.6 thousand ha	Substantial irrigated agriculture
Rainfed area	223.4 thousand ha	Persistent exposure to monsoon variability
Net dynamic groundwater availability	1,033 MCM	District-scale groundwater endowment remains significant
Gross groundwater draft for all uses	354 MCM	Groundwater use is substantial, even where canal systems exist
Groundwater status	Mostly safe units, but overexploited pockets in Bollapalli mandal	Average district position masks localized stress

Note: Compiled from ICAR-CRIDA district contingency data and CGWB groundwater assessment reports for the undivided Guntur district.

The resource figures on the ground water bring in a significant touch. According to the CGWB NAQUIM report, the availability of net dynamic replenishable groundwater is approximately 1,033 MCM, and the gross groundwater draft is approximately 354 MCM meaning that the entire district is not uniformly overdeveloped on the aggregate level (CGWB, 2022a). Nevertheless, overexploited villages in Bollapalli mandal are also identified by the district contingency profile, and even Ground Water Year Book records pre-monsoon water levels more than 10 m in Guntur, which is also clear evidence of spatial and seasonal stress (CGWB, 2022b; ICAR-CRIDA, n.d.). That is, the average conditions of uniformly secure groundwater should not be confused with the district averages.

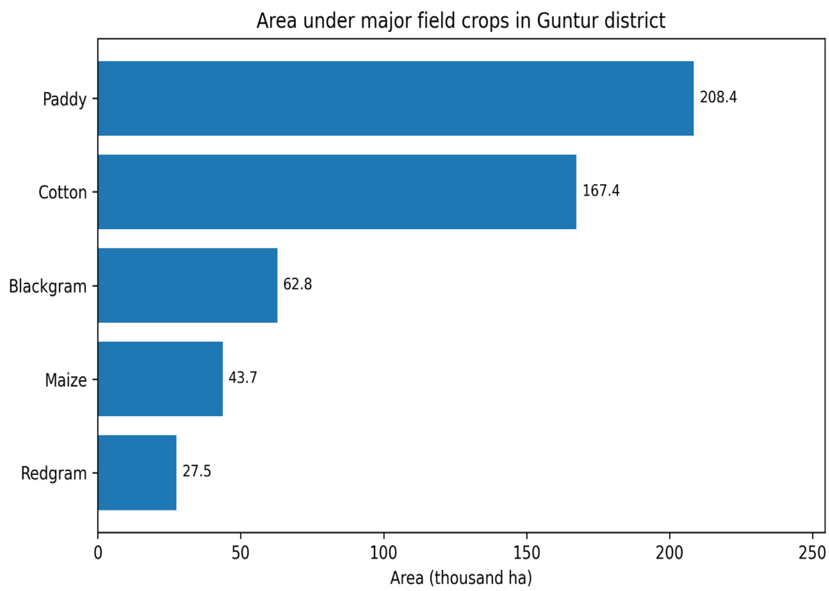

Figure 1. Area under major field crops in Guntur district (thousand ha). (Source: Redrawn from ICAR-CRIDA district contingency statistics for Guntur).

4.2 Cropping pattern and water demand implications

The crop system also explains why groundwater is still at a strategic level despite the existence of canals irrigation. According to official district statistics, paddy and cotton occupies the most area of major field crops, next comes blackgram, maize and redgram. This trend is important in that paddy is a crop which requires water and cotton and commercial crops which consume sustained irrigation demand at the most critical points in their growth cycle. The enrichment of production in these kinds of crops raise the worth of water reliability not only water availability in the abstract. Figure 1 shows the dominance of paddy (208.4 thousand ha) and cotton (167.4 thousand ha), with pulses and maize occupying smaller but still important areas. This composition has two implications. First, agricultural productivity in the district depends on the continuity of irrigation supplies across seasons. Second, localized groundwater decline can have asymmetric effects: it may not collapse district-wide production immediately, but it can sharply affect non-canal pockets, tail-end farmers, and borewell-dependent villages where groundwater functions as the main stabilizing source.

Table 2. Selected crops and average productivity in Guntur district

Crop	Average productivity (kg/ha)	Interpretive note
Paddy	6,541	High output, but strongly linked to reliable irrigation
Cotton	2,329	Commercial crop with significant moisture sensitivity
Blackgram	817	Lower productivity and often more rainfall-sensitive
Maize	8,529	High productivity under improved input and water conditions
Redgram	1,191.5	Important pulse crop with lower yield than irrigated cereals
Sugarcane	96,429	Very high biomass productivity but highly water demanding

Note: Productivity figures are district-level averages reported in the ICAR-CRIDA contingency profile.

Table 2 reinforces that crops with assured water access achieve much stronger productivity outcomes than crops that remain more exposed to rainfall variability. This does not imply that groundwater alone determines yield; inputs, soils, seed choice, and management also matter. But it does mean that the district's productivity profile is structurally tied to dependable irrigation. For this reason, groundwater should be treated as a productivity-stabilizing asset rather than simply an extractive reserve.

4.3 Irrigation structure and the role of groundwater

The irrigation system of Guntur is more sophisticated than the general thinking that the district is all borewell based. Canals due to official district data, take up the most significant portion of irrigated area, next bore wells, and then lift irrigation, tanks, and other sources occupy comparatively small portions. This is an embodiment of the co-existence of the surface-water command zones and the groundwater-based agricultural systems. Policy wise this is significant in the sense that conjunctive use should be viewed as the primary framework of groundwater management in Guntur and not in isolation of groundwater.

Even though the area of canal irrigation prevails at the district aggregate, groundwater is vital in at least three aspects. To start with, it smooths out rainfalls shocks in sites which are external or poorly covered by canal networks. Second, it augments canal supplies in the event of timing or carry inadequacy. Third, it fosters the flexibility of crop choice, especially on commercial crops and dry-season cultures. This is in line with the larger Indian evidence which demonstrates that groundwater grants farmers independence, timeliness, and buffering of risk that surface systems do not tend to be able to offer (Shah, 2009; Fishman, 2018). Another applicable productivity dimension is groundwater quality. A recent examination of 225 groundwater samples in Guntur district identified that 79.6% of the samples belonged to the excellent irrigation category and 12.9% to the good category albeit with lower proportion reporting limitations associated with risk of salinity and sodicity (Sudha Rani et al., 2023). This implies that groundwater will continue to be economical in agricultural activities of the district, however, quality degradation in certain areas can exacerbate the consequences of decreasing supply.

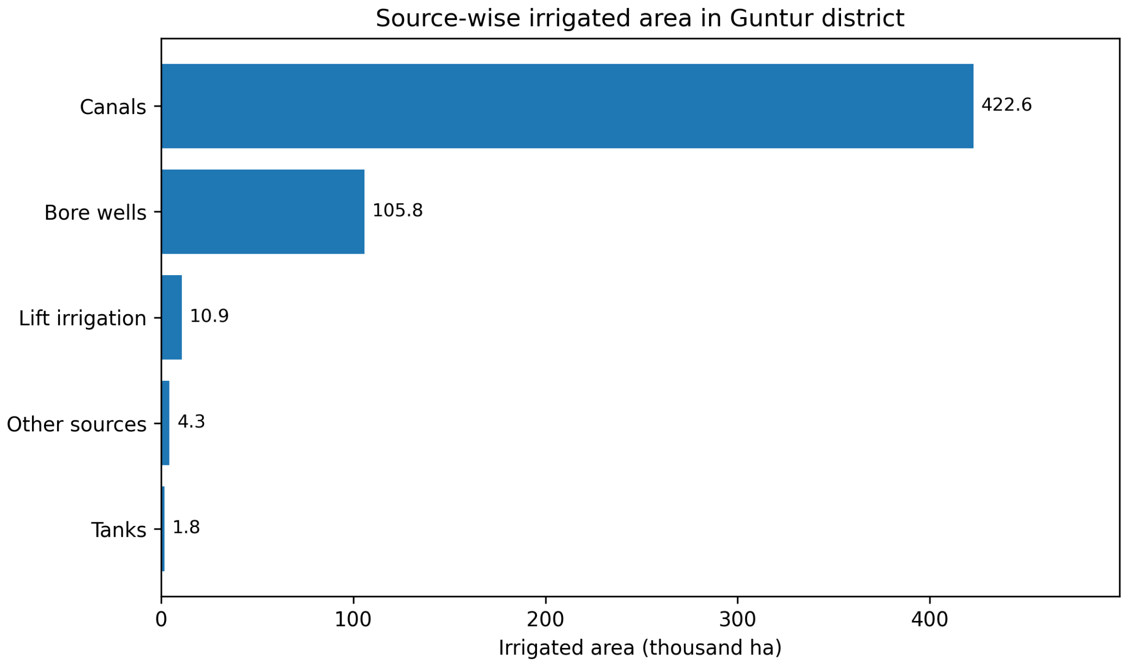

Figure 2. Source-wise irrigated area in Guntur district (thousand ha). (Source: Redrawn from ICAR-CRIDA district contingency statistics for Guntur.)

4.4 Implications for sustainable agricultural productivity

The facts seem to have been leading to a very simple, yet significant conclusion, that agricultural productivity in Guntur is not the matter of rainfall, nor of a groundwater store, but of the dependability and control of a conjunctive irrigation regime. There is seemingly sufficient groundwater availability at the district level, but local overuse and seasonal reductions are indicators that there is vulnerability to local overuse where crop demand and pump pressure are highly sought. This may allow productivity to be very high over a period of time and the resource base is undermining. This trend is similar to national research studies. Satellite and modelling investigations revealed that groundwater exploitation in India can lower the intensity of the crop, augment exposure to the variability of the rainfall, and undermine the ability of farmers to adjust to the climate stress (Rodell et al., 2009; Fishman, 2018; Jain et al., 2021). Hence, the fact that the current production is high cannot be viewed as a sign of a long-lasting sustainability. In the case of Guntur, there are five policy directions which are particularly relevant. To start with, groundwater and canal systems must be handled in conjunction with planning being developed where groundwater serves as a buffer as opposed to being the only source. Second, recharge needs focused on stressed pockets as opposed to implementing a uniform recharge measure. Third, commercial and high-water crops should be given preference to micro-irrigation and better scheduling of irrigation. Fourth, less water-intensive alternatives in stressed borewell regions should be speedily promoted by crop planning. Fifth, monitoring needs to shift to an area-average of acceleration of the groundwater depth and quality to village- and mandal-level. These guidelines coincide with the general literature on groundwater governance demonstrating that technical solutions are only effective when accompanied by institutional targeting and enforcement at the local level (Aeschbach-Hertig & Gleeson, 2012; Msangi and Cline, 2016; Dangar et al., 2021).

5. LIMITATIONS

This study relies on secondary data available at the district level, which naturally places some limits on the analysis. It does not draw on household survey data, farm-level econometric modelling, or time-series estimation linking groundwater conditions with crop yield. Another important point is that the statistics used in the study correspond to the undivided Guntur district boundary followed in the source documents. For that reason, the results should be read as a systematic district-level assessment, not as a direct causal explanation or a plot-level production analysis. Future research can strengthen this work by using mandal-level groundwater time-series data, remote-sensing estimates of cropped area, and farmer-level information on irrigation practices to better measure how groundwater stress affects agricultural productivity.

6. CONCLUSION

Guntur district is one of the stronger agricultural regions in terms of production, and that strength rests heavily on how well water is available and managed. Its rainfall pattern, high cropping intensity, and large irrigated area all point to a solid agricultural base. At the same time, groundwater estimates suggest that the district as a whole is not yet under uniform water stress. Still, that broader picture should not create false confidence. In several pockets, groundwater is already under pressure, pre-monsoon water levels are falling deeper, and the continued cultivation of water-intensive crops raises concerns about long-term sustainability. The real message, therefore, is not that Guntur has run out of groundwater, but that its present productivity may become increasingly difficult to maintain if local overuse, water quality decline, and inefficient irrigation practices are allowed to continue. A more balanced and durable approach is needed. Improving canal use, strengthening groundwater recharge, expanding micro-irrigation, encouraging crop diversification, and maintaining stricter local monitoring together offer the most practical way to safeguard both groundwater resources and agricultural productivity in the district.

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