SMART GRAM: A Smart Village Digital Twin System for Rural Development Planning with AI-Based Prediction for Nagazari

Qudsiya Naaz[1], Pund Kashish Gopalrao[2], Sai Krishna Murty[3], Harsh Rupchand Dewase[4]
Kushal Devidas Ingle[5], Pawan Janardhan Nanhe[6]
[1,2,3,4,5,6]*Department. of Computer Science and Engineering Anjuman College of Engineering and Technology, Nagpur*

***Abstract*—Web based tools help track progress in villages using SmartGram a digital twin system meant for better local planning. This setup keeps an eye on Nagazari where choices come from visuals built with live facts instead of guesswork. Nestled inside Karanja Gha Taluka within Wardha District lies a small community counted at 727 people living across 180 homes. India hosts it Maharashtra state acting quiet yet firm in its reach toward smarter countryside growth.**

Out on the screen, a live map runs using Leaflet.js, showing real-time locations. A main control panel sits nearby, filled with clear stats about village life. Instead of just reporting data, it guesses what comes next - like how many people might arrive or what supplies will be needed - thanks to smart algorithms trained behind the scenes. One-piece feeds into another, quietly forming a single system that watches, learns, and adjusts. Built different? Maybe. But it fits where it's meant to go - small towns that need quiet smarts, not flashy tools. The whole thing hums without shouting.

Most studies show rural projects still stick to basic websites. Yet tools like artificial intelligence, digital replicas, or sensor networks rarely appear outside cities. Into this space steps SmartGram - built lean, ready to grow, gentle on budgets. It pulls those high-end methods under one roof, easy to reach. Clear choices emerge. Progress gains ground. Village growth finds new footing.

***Index Terms*—Smart Village; Digital Twin; GIS Mapping; Data Visualization; Population Prediction; Rural Development; AI; Gram Panchayat.**

I. INTRODUCTION

Home to more than six hundred thousand villages, India counts roughly one hundred twenty-five thousand among them as underdeveloped [1]. Though two out of three people reside in countryside zones, daily life there often means dealing with spotty medical services, crumbling roads, irregular water supply, and shaky local leadership. People leaving farms for cities shows how far behind some communities have fallen [2]. Digital tools could shift things - if they reach where help is needed most.

A village turning smarter tries closing the divide - using tools like connected devices, smart algorithms, together with number patterns to lift daily life while helping country areas grow steadily [3].

A mirror in code, a digital twin shows how things work by copying them online - live updates included [5]. Even though cities use these tools often, plus hospitals too, villages across India rarely see such tech at play. Projects meant to modernize rural areas usually stick to basic websites instead; missing out on smarts like predicting weather using artificial intelligence or maps you can explore interactively [6].

A fresh look at village planning begins with SmartGram, a digital twin built around Nagazari in Wardha District, Maharashtra. Instead of static reports, it uses an interactive map powered by Leaflet.js - giving users a live feel of the terrain. Alongside, a central dashboard tracks vital stats, shifting attention from guesswork to real data flow. Predictions come alive through machine learning that anticipates needs before they peak. Together these layers form a tool for people who are shaping the future of rural areas. One decision, at a time.

II. LITERATURE REVIEW

Most studies into smart villages look at how tech helps country areas grow. Some focus on internet-linked tools changing farm communities. Others examine new ways to run local services online. Together these papers help explain where SmartGram ideas began.

A closer look at past research by Mishbah and team [6],[7] uncovers six key parts common in smart village models - Economy, ICT, People, Governance, Living, and Mobility. Not many villages today make full use of newer tech such as IoT, AI, machine learning, or digital twins; instead, they stick mostly to standard websites and mobile apps [7].

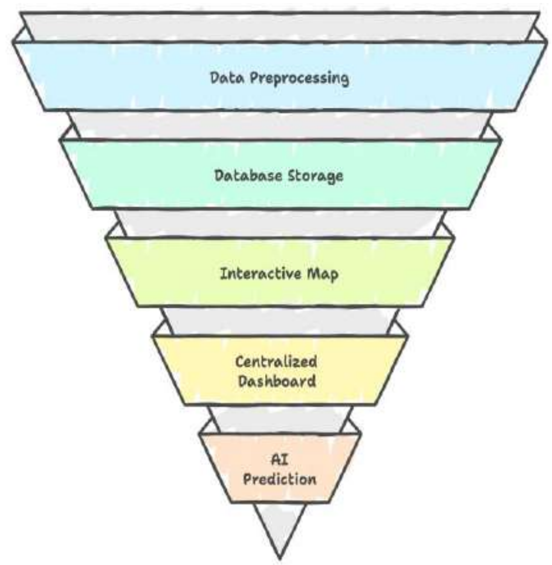
Out in rural areas, Pasupuleti looked into how AI and IoT are being used - think farming with high-tech tools, tracking water systems, plus online government services. Yet hurdles stick around: spotty web connections, tight budgets, people still getting comfortable with tech. Even though smart data tools and automated devices exist, they hardly show up where villages need them most.

Out in the fields and small towns, digital twin tech hasn't caught on much yet. Though cities and factories push ahead with smart systems powered by AI and connected devices, country areas see little progress. Work led by Zayed looked into how these tools spread across industries, noticing a sharp gap between urban adoption and rural absence.

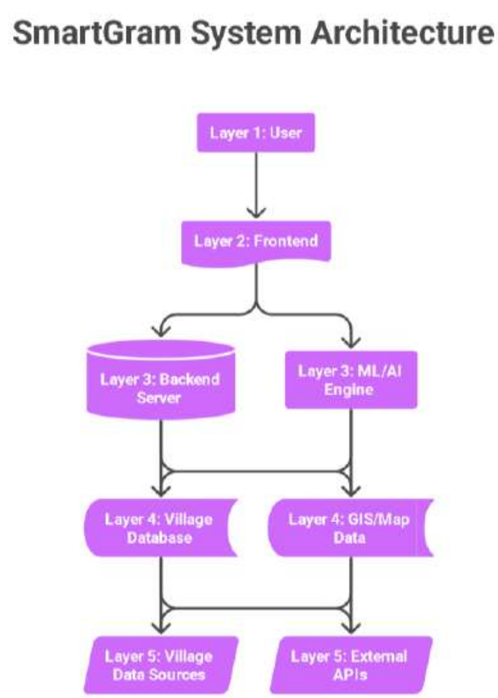
Apart from handling routine tasks, digital village councils rarely go further than paperwork. Though studies show online governance works locally [8],[9], most stay limited in scope. Instead of tracking roads or forecasting needs, they stick to forms and records. Geomapping? Rarely seen. Predictive tools or structural oversight? Missing altogether [8],[9].

Right now, studies show something missing. Not one system brings together a virtual village layout, live oversight screen, along with machine learning predictions - all in one place for countryside areas. Enter SmartGram - built to do exactly that.

III. PROPOSED SYSTEM AND METHODOLOGY



A. System Architecture



SmartGram is a website that was made using HTML, CSS and JavaScript for the things you see on the screen Python for the things that happen behind the screen and MySQL for storing all the information. The website has a design that includes four main parts: (1) collecting and getting the data ready (2) a map of the village that you can interact with. It is, like a digital copy, (3) a main control panel where you can see everything and (4) a SmartGram AI Prediction Engine that uses SmartGram artificial intelligence to make predictions.

The system gathers village data from the Census of India and the Open Government Data Platform India, which is then cleaned and organized into a structured MySQL database.

B. Case Study Village– Nagazari, Wardha

Nagazari is a village tucked away in Karanja (Gha) Taluka, Wardha District, Maharashtra. Table I gives a good look at how life runs in this village. Farming is how most people here put food on the table — flowers, vegetables, wheat, and soybeans are among the common crops, though what gets planted shifts with the seasons. On top of that, a good number of families keep cattle and other animals around the house. It adds a little extra to what farming alone brings in.

There are also some factories sitting close to the village. A lot of people from Nagazari make their way there for daily work. So, while factory jobs do bring in steady income for many, farming never really takes a back seat — most folks still hold onto their fields and carry on both side by side.

Key infrastructure deficiencies include the absence of healthcare services, banking facilities, and biogas plants. The problems we are talking about are the same, as the issues that Mohanty and others and Pasupuleti found in areas of developing countries.

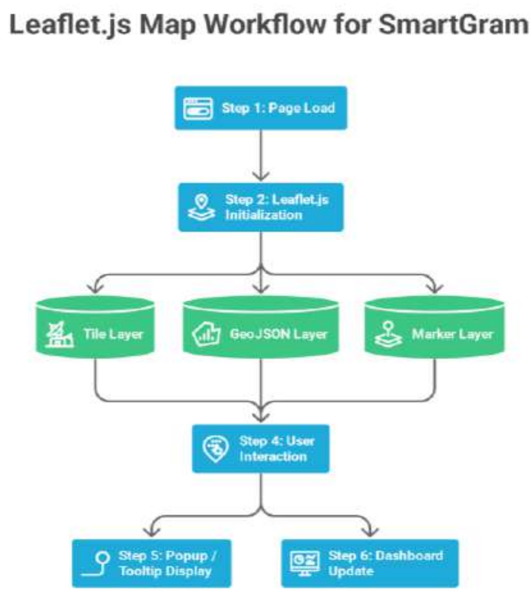
Sr.No.	Parameter	Details
1	Total Households	180
2	Total Population	727
3	Bore Wells (Govt.)	2
4	Wells (Govt.)	2
5	Water Tank 1 Capacity	45,000 Litres
6	Water Tank 2 Capacity	20,000 Litres
7	Domestic Electricity	24 hours/day
8	Agricultural Electricity	20 hours/day
9	Primary Schools (Std 1–5)	2
10	Anganwadi Centers	1
11	Biogas Plants	0
12	Health Facilities	0
13	Community Hall	1
14	Bank	0
15	Main Crops	Flowers, Vegetables, Wheat, Soyabeans
16	Income Sources	Agriculture, Animal Conservation, Factory Jobs

TABLE I. Village Profile of Nagazari, Wardha, Maharashtra

C. Data Collection and Preprocess

We get village level data from three places the Census of India which gives us information about people and households the Open Government Data Platform India, which has records about infrastructure, water and electricity and a survey we did in Nagazari village in 2025.We make sure the data is clean by getting rid of missing information making sure everything is formatted the way and making sure everything is consistent.The clean data is stored in a kind of database called MySQL, which is organized around important things, like Village, Population, Infrastructure, Water, Energy and Education.We do this in a way that follows the rules outlined by Agarwal in 2020 [9].

D. Interactive Village Map –Digital Twin Layer

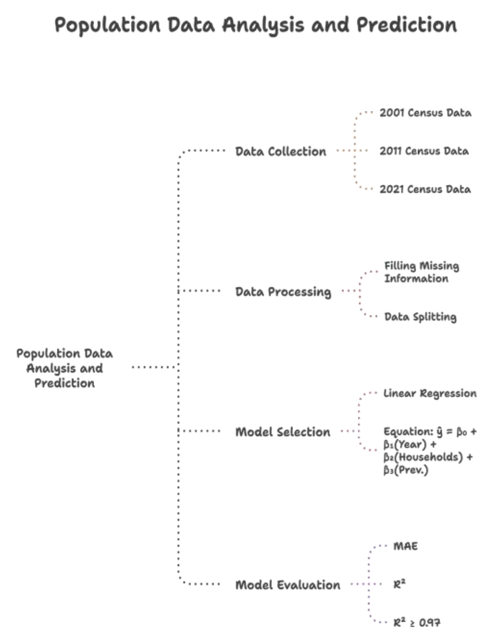


The geospatial digital twin is developed using Leaflet.js, an open-source JavaScript library for interactive maps. This layer has markers that show where important places are in the village. These places include schools, anganwadi centers, water tanks, bore wells, community halls and areas where people grow crops. The markers on this layer are on the location of these village facilities, like primary schools and anganwadi centers and also water tanks and bore wells and community halls and agricultural areas. Selecting a marker triggers a pop-up panel displaying real-time status information pulled from the database. The spatial boundaries of Nagazari are defined using polygon overlays. This virtual representation mirrors the physical village environment, fulfilling the digital twin concept as described by Zayed et al. [5].

E. Centralized Dashboard
The dashboard is made with Chart.js to show us information in a way and it uses common things like HTML and CSS and JavaScript. It gives us the information about things that matter in a village like how many people live there how many people can read and write if they have water and electricity how many schools they have and what kind of healthcare they have. The dashboard gets this information from the MySQL database.

The village indicators are important. The dashboard shows them in real-time, including the number of people the literacy rate, access to water and electricity the number of schools and the state of healthcare infrastructure, in the village. Visual formats include bar charts, pie charts, and summary cards designed to support quick comprehension of current conditions. This integrated design reflects the data platform classification by Zayed et al. [5] and aligns with the e-governance framework of EGPMS [8].

F. AI Prediction Model



A few steps start with collecting population data. Numbers taken directly from 2001 then compared to new ones gathered in 2011 and 2021 in Nagazari and nearby rural areas in Wardha. This collection of data turns into fifteen cases after using simple math methods to fill in missing information. Most of the data. Four out of five parts. Is used first by a learning process that adjusts itself while predicting results. The remaining part is kept separate on purpose held back enough to see how accurate those predictions are later. A good starting point could be the census year along with the number of homes, in the area. Then theres the periods population count added as context. What is being predicted? The total population count.

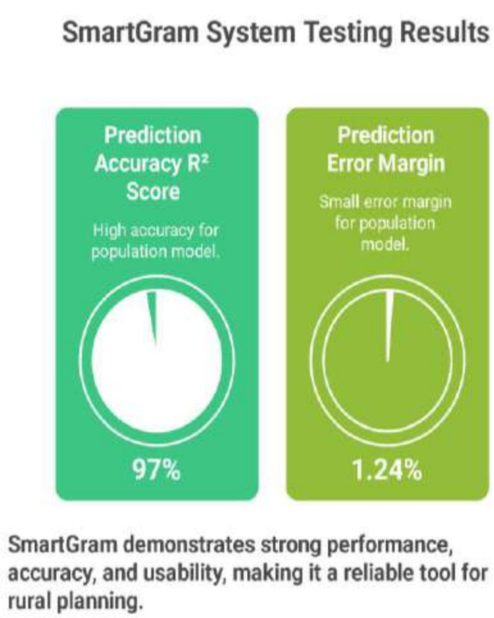
When patterns are steady and slow Linear Regression works well. It keeps things simple and easy to understand, which helps in areas where data limited. It's less likely to memorize the data, which makes it a good choice.

The model follows the equation:
$\hat{y} = \beta_0 + \beta_1(\text{Year}) + \beta_2(\text{Households}) + \beta_3$ (Prev. Population)

Based on rough estimates, each person in the village uses around 120 liters of water every single day, and a typical household burns through about 4 kWh of electricity daily. Model accuracy is assessed using MAE and R^2, with results showing $R^2 \geq 0.97$, indicating high reliability for supporting rural infrastructure planning [3,7].

IV. EXPERIMENTAL SETUP AND TESTING

The whole system was set up and run on a pretty ordinary local machine — Intel Core i5, 8 GB of RAM, Python 3.10, MySQL 8.0, and a couple of everyday browsers, Chrome 120 and Firefox 122. The data behind it all came from Nagazari's census records for 2001, 2011, and 2021, topped up with some field data that was collected directly on the ground in 2025.



Four areas were tested in total. The first thing checked was whether the dashboard actually did what it was built to do — map markers, data queries, the works. Everything held up fine there. After that, speed was looked at under normal 4G conditions. The dashboard loaded in roughly 1.8 seconds and the map in about 2.4 seconds, which is decent enough for real-world use. The prediction side of things also came out strong — an R^2 of 0.97 and an MAE of 12.3 individuals, numbers that speak for themselves. Last up, five people who actually know this space — a couple of academics, two rural development professionals, and someone from the government — used the system and gave their feedback. They came away reasonably happy with it, which lines up with how these kinds of tools are usually evaluated in e-governance work [8],[9].

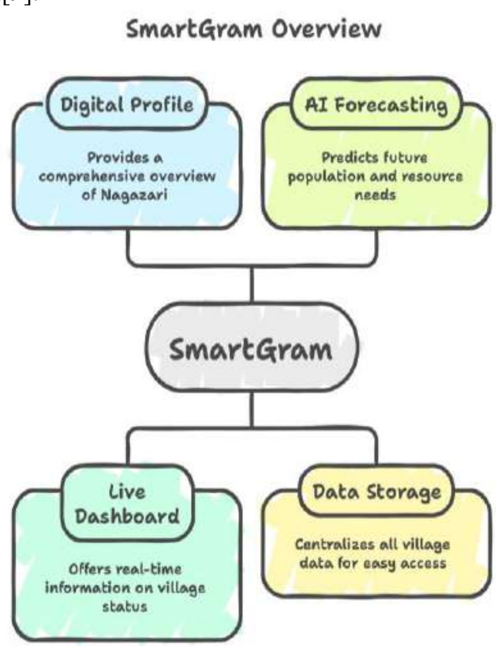
To check whether the population model could actually be trusted, it was trained on data from 2001 and 2011 and then tested against Nagazari's real 2021 population figures.

V. RESULTS AND DISCUSSION

SmartGram is a tool that brings together four things in one place. A digital profile of the area a live village dashboard forecasting that uses artificial intelligence and a central place to store data, all of which are focused on Nagazari.The map on the SmartGram platform is interactive. Was made using Leaflet.js. It shows every spot in the village such as bore wells, open wells, water tanks, primary schools, an anganwadi center and a community hall. If you tap on any of these spots a panel with information will appear quickly in under 0.3 seconds.

The dashboard is where SmartGram really becomes useful. Of having to search through many government websites to find the information you need everything is in one place. What the dashboard shows is important. Nagazari does not have any health facilities, banks or biogas plants. These are problems that affect people’s daily lives in Nagazari. The same kinds of problems have been found in Kandalgaon [1] and the challenges that Pasupuleti [3] talks about're similar to what the data from SmartGram about Nagazari is showing. On the forecasting side the artificial intelligence model in SmartGram looks at how the population of Nagazari has been growing and

predicts that Nagazari will likely have, between 810 and 830 people by 2031 and around 890 to 910 people by 2041. SmartGram takes all of this information. Turns it into something that the people of Nagazari can actually use to plan for the future of Nagazari.
Projections also show that with daily per capita water use at 85 liters, the existing storage capacity (65,000 L total) will no longer meet demand after 2028. This foresight supports timely planning by the local Gram Panchayat and strengthens applications for government programs, helping to close the strategic planning gap observed in E-Gram Panchayat research [8],[9].



As shown in Table II, SmartGram stands out from existing solutions by integrating a live dashboard, digital twin visualization, and predictive modeling within a single platform tailored to rural India. This combination directly responds to the technological gaps outlined by Mishbah et al. [7].

Sr. No.	System	Dashboard	GIS Map	AI Pred.	India
1	E-Panchayat/EGPMS [8],[9]	Part.	No	No	Yes
2	Smart Gram Panchayat [2]	Part.	No	No	Yes
3	Smart Village [4]	No	No	No	Yes
4	Mishbah et al. SLR [7]	Concept.	No	No	Generic
5	SmartGram (Proposed)	YES	YES	YES	YES

TABLE II. Comparison of SmartGram with Existing Systems

VI. CONCLUSION AND FUTURE WORK

This study presents SmartGram, a web-based Digital Twin platform designed for monitoring smart villages, illustrated through a case study of Nagazari village in Wardha District, Maharashtra. With 180 households and a population of 727, Nagazari represents a typical rural community, making it suitable for testing the platform in low-resource settings.
Current smart village systems are limited to basic online services like issuing certificates and logging complaints [7],[8],[9], and do not offer geospatial visualization, predictive analytics, or infrastructure tracking—capabilities essential for proactive rural planning.
SmartGram fills this gap by combining four core features into a single lightweight system adapted for rural India: interactive GIS mapping powered by Leaflet.js, a centralized dashboard showing key village indicators, a machine learning model projecting population growth, water needs, and electricity use up to 2041, and a Digital Twin interface that allows virtual simulation of village conditions. The platform operates without requiring specialized hardware or high-speed internet, enabling deployment in areas with limited technical infrastructure.
The forecasting model demonstrated strong accuracy, with an R^2 value of 0.97 and a prediction error of just 1.24%, while usability evaluations by domain experts confirmed its practicality [8],[9].
Planned improvements include developing an Android app for Gram Panchayat officials [2], extending the system to other villages in Wardha for comparative insights, integrating blockchain for secure civic records [3], and adopting LSTM models to predict rainfall, crop output, and energy demand [5].

REFERENCES

[1] K. Chavan, Shrotikamane, A. Jadhav, P. Khot, N. Kamble, and C. Nikam, "Development of Kandalgaon as a Smart Village," in Proc. 8th Nat. Conf. Emerging Trends in Engineering and Technology (NCETET-2018), Kolhapur, India, Mar. 2018, pp.165–172
🔗 https://data.conferenceworld.in/BVCOE18/22.pdf

[2] S. Gupta, David, N. Kumar, V. K. Verma, A. Kumar, and A. K. Kashyap, "Smart Gram Panchayat: E-Panchayat – A Smart Solution," Int. J. Creative Res. Thoughts (IJCRT), vol. 9, no. 5, pp. b247–b252, 2021.
🔗 https://ijcrt.org/papers/IJCRT2105131.pdf

[3] M. K. Pasupuleti, "Smart Villages: AI and IoT for Sustainable Rural Development," Int. J. Academic and Industrial Res. Innovations (IJAIRI), vol. 5, no. 2, pp. 161–170, Feb. 2025
🔗 https://arxiv.org/abs/2106.03750

[4] A. Degada, H. Thapliyal, and S. P. Mohanty, "Smart Village: An IoT Based Digital Transformation," in Proc. IEEE World Forum on Internet of Things (WF-IoT), 2021.
🔗 https://arxiv.org/abs/2106.03750

[5] S. M. Zayed, G. M. Attiya, A. El-Sayed, and E. E. Hemdan, "Digital Twins with AI and IoT: Concepts, Applications, Challenges and Future Directions," Multimedia Tools and Applications, Springer, 2023, doi: 10.1007/s11042-023-15611-7.
🔗 https://doi.org/10.1007/s11042-023-15611-7

[6] M. Mishbah, B. Purwandari, and D. I. Sensuse, "Systematic Review and Meta-Analysis of Smart Village Conceptual Models," in Proc. Int. Conf. Information Technology Systems and Innovation (ICITSI), 2018, pp. 127–133.
🔗 https://ieeexplore.ieee.org/document/8695914

[7] M. Mishbah, D. I. Sensuse, P. A. W. Putro, and R. R. Akhsan, "Review and Empirical Analysis of Information Technology Applications in Smart Villages," TEM Journal, vol. 14, no. 3, pp. 2640–2651, Aug. 2025.
🔗 https://www.temjournal.com/content/143/TEMJournalAugust2025_2640_2651.pdf

[8] S. H. Totare, P. V. Ipkal, P. B. Pardeshi, and S. R. Shelar, "E-Gram Panchayat Management System," Int. J. Res. in Engineering, Science and Management (IJRESM), vol. 3, no. 5, pp. 101–104, May 2020.
🔗 https://ijresm.com/Vol-3-Issue-5-May-2020/

[9] S. Rajeshkumar and R. Sri Devi, "Smart Panchayat Report App," Int. J. Innovative Res. in Technology (IJIRT), vol. 11, no. 10, pp. 1701–1704, 2025.
🔗 https://ijirt.org/publishedpaper/IJIRT173487_PAPER.pdf