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Evolution and Spatial Distribution of Agricultural Technology in Jalgaon District: A Decadal Analysis (1971–2021)

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ABSTRACT

This study examines the spatiotemporal patterns of agricultural technology in the Jalgaon district of Maharashtra, covering a significant reference period from 1971 to 2021. Agriculture remains the backbone of the regional economy, yet its growth is increasingly dependent on the transition from traditional implements to modern mechanized and digital solutions. The research analyzes the shifting reliance on wooden and iron ploughs against the backdrop of rising population pressure and the adoption of modern "Agri-tech.". The methodology utilizes decadal data from the statistical department of Jalgaon to evaluate the density of farm implements per thousand hectares of cultivated area. Findings reveal a significant turning point after 1991; while the number of wooden ploughs peaked at 63,000 in 1991, their density dropped sharply to 42.37 by 2011. Similarly, iron ploughs saw a decline from a peak density of 59.75 in 1991 to 28.36 in 2011, signalling a move toward tractorization and advanced machinery. The study further identifies a geographical divide: remote tribal settlements in the Satpuda and Ajantha ranges (northern Jalgaon) maintain higher densities of primitive tools due to rugged terrain and socio-economic barriers. Conversely, developed tehsils like Bhusawal and Jalgaon are leading the transition toward drip irrigation (especially for banana cultivation) and AI-powered precision farming. The paper concludes that while technological diffusion is essential for food security, the fragmentation of land holdings remains a critical barrier to full-scale mechanization in the region.

1. Introduction

The prosperity of an agrarian economy and the optimization of land use are fundamentally tethered to the level of technology employed in the field. As global food demands surge, technology has emerged as the most reliable force for driving higher land productivity. Improvement in farm technology is not merely a choice but an essential requirement for increasing agricultural output; the full potential of any rural landscape remains locked until innovative changes occur in farming techniques. Historically, technologies were developed as survival mechanisms-tools designed to overcome pressing environmental constraints and simplify the rigors of human labour [1, 2].

In the context of modern agriculture, the use of sophisticated implements and machinery is vital for enhancing productivity. These tools increase operational efficiency, save time, reduce the physical burden of manual labour, and significantly minimize production costs. Contemporary farming is currently witnessing a paradigm shift where traditional, time-consuming methods are being replaced by high-efficiency machines. A series of scientific methods-including the judicious use of fertilizers and advanced soil management-have been integrated to realize the latent fertility of the soil. Consequently, substantial improvement in agriculture depends largely on the propagation and diffusion of innovations across rural communities [3].

However, the adoption of these technologies is often dictated by local constraints. A primary factor is the size of agricultural land holdings. While modern machinery is highly profitable on large-scale farms, its efficiency suffers in regions where plots are small and fragmented. In the study region of Jalgaon district, small land holdings often act as a significant barrier to the implementation of full-scale mechanization [4].

The relationship between agricultural techniques and land use is cyclical. In the initial phases of land use, soil fertility is often maintained through fallowing. However, as population pressure increases, the "annual cropping phase" begins, leaving no extra land for extension. In such scenarios, the risk of diminishing returns due to soil exhaustion becomes a reality. To maintain food consumption levels for a growing population, the adoption of newer technology becomes inevitable [5].

The historical progression of technology can be categorized by the tools used:

- *Forest Fallows*: Associated with axes and digging sticks.
- *Bush Fallows*: Associated with the hoe.
- *Short Fallows*: Associated with the plough.
- *Multi-cropping Systems*: Associated with modern sophisticated technology.

The reference period for this study (1971 to 2021) provides a comprehensive window to observe the temporal and spatial diffusion of agricultural technology in the Jalgaon district of Maharashtra. Jalgaon is unique in its technological landscape; it is a global leader in banana cultivation, which has necessitated the widespread adoption of modern irrigation techniques like drip irrigation.

Furthermore, the region is beginning to integrate artificial intelligence (AI) for precision farming in crops like sugarcane. Farmers are increasingly utilizing AI-powered platforms to manage irrigation, fertilization, and pest control based on real-time soil data. This transition-from the primitive wooden ploughs still used in the remote Satpuda and Ajantha ranges to AI-driven precision tools-represents a dual-speed technological landscape that this study aims to analyze.

The proper use of agricultural land and higher output is totally depending on the technology which is used. The technology has been the most reliable force for pushing towards higher productivity of land [6]. Improvement in farm technology is essential requirement for increasing agricultural production. Full utilization of farm potential is not possible unless sufficient innovative changes occur in agricultural techniques. Technologies were developed to overcome the pressing problems and make life easier [7].

The use of agricultural implements and machinery is considered as the important for enhancing the productivity from the land because their use increases farm's efficiency, save the time, hard work, labours and minimizes production cost. Modern agriculture is witnessing a technological change in which the farmer is inclined to use better

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machines in place of archive and time-consuming ones. It has been proved through a number of studies that the judicious use of farm machinery and implements can play a very important role in increasing agricultural productivity.

The new agricultural technologies have played a significant role not only in minimizing environmental risk but also have increased the yield levels of crops. A series of methods have been involved to increase productivity by using fertilizers and better techniques to realize the potentials of soil fertility. A speedy and substantial improvement in agriculture by and large depends on by bringing technological change and propagation of diffusion of innovations [8].

The use of machinery depends on certain condition of which size of field occupies. Most of the machines and farm implements may prove profitable on large size farms but their efficiency suffers if plots are of small. The agriculture land holding in study region is small hence it is barrier to implement of mechanization.

Improvement in farm technology is essential prerequisite for increasing agricultural production. Full utilization of farm potential is not possible unless sufficient innovatory changes occur in agricultural techniques [9]. Successive changes in land use system of a region are accompanied by equivalent technological changes in farming to cultivate satisfactory farm output for growing rural community. In the initial phases of land use pattern grow the soil fertility of the farmland because each plot of land was left uncultivated for number of year sufficient for the soil to regain nutrients.

As land use grows however, comes the annual cropping phase when no extra land is available for agricultural extension. In some regions the situation of diminishing return from the farm land develops because of the rapid exhaustion of soil fertility due to continued and uninterrupted cropping on the farm. Adoption of newer agricultural technology is inevitable and advantageous in such situation for maintaining the previous level of food consumption of people in consistently growing human population. It has been shows that there is close relation between agricultural techniques and land use types. The present land use system of the world shows that, the forest fallows are associated with axe and digging sticks, the bush fallow with the hoe, the short fallow with the ploughs and multi-cropping system with the modern sophisticated technology [10].

The reference period of the present study 1971 to 2021, is sufficient for the study of changes in agricultural techniques and their diffusion in Jalgaon district. An interpretation of the temporal and spatial aspect of agricultural technology would help in understanding and substantiating the validity of interdependence land use system and farming techniques. With the increasing population, food demand also increases hence for maintaining this demand farmers used modern sophisticated farm equipment and trying for increase the production. Though adoption of modern technology is in fever to fulfil the demand of present population whenever in small parts of farm we cannot use these modern techniques.

Agricultural technology in the Jalgaon district of Maharashtra includes modern irrigation techniques like drip irrigation, particularly for its significant banana cultivation, and the integration of Artificial Intelligence (AI) to help farmers with precision farming for crops like sugarcane. Farmers use AI-powered platforms to manage irrigation, fertilization, and pest control using real-time soil data and historical patterns for more informed, data-driven decisions. Widespread use of drip irrigation is a hallmark of Jalgaon's agricultural technology, especially for its famous bananas, ensuring water efficiency.

Agricultural technology (Agri-tech) plays a critical and transformative role in agricultural development by enhancing productivity, ensuring sustainability, and boosting economic growth and food security worldwide. It provides innovative solutions to meet the growing global food demand while addressing environmental and climate change challenges. Advanced machinery, automated tractors, and robotics perform labour-intensive tasks like planting, harvesting, and weeding faster and more accurately than manual labour. This reduces the physical burden on workers and addresses labour shortages.

2. Farm Preparation Technology

The plough or plow is a tool used for initial cultivation for preparing soil. Ploughs are traditionally pulled by domestic animals such as bullocks, horses or cattle, but in modern times may be drawn by tractors. A plough may be made of wood, iron or steel. It has been a basic instrument for the most of recorded history and represents one of the major advances in agriculture. The primary purpose of ploughing is to turn over the upper layer of the soil, bringing fresh nutrients to the surface, while burying weeds, the remains of previous crops and both crop and weed seeds, allowing them to break down. It also provides a seed-free medium for planting an alternate crop.

2.1 Wooden Ploughs

Wooden ploughs are primitive mechanical techniques used for agricultural cultivation. Today also used Wooden ploughs for cultivation in some of the remote forest tribal settlements of the northern part of Jalgaon district (Satpuda, Ajantha ranges). In the northern part of Jalgaon district mainly used wooden plough because the productivity of this rugged land is not sufficient to used modern sophisticated technology. Partition of farming land with the dividing families also make barrier in improvement in agricultural technology. According to Table 1, in 2011 37087 are total number of wooden ploughs in Jalgaon district. Among them the highest numbers of wooden ploughs are observed in Jalgaon tehsil that is 5867 while the lowest numbers of wooden ploughs are observed in Jamner Tehsil that is 105. The highest density of wooden ploughs is observed in Jalgaon tehsil that is 98.75 per sq. thousand hectare cultivated area. The lowest density of wooden ploughs is noted in Jamner Tehsil that is only 1.03 per Sq. thousand hectare cultivated area [11]. The average density of wooden ploughs in Jalgaon district is 42.37 per sq. thousand hectare cultivated area. Uses of wooden ploughs are maximum in undeveloped area compare to developed area.

Table 1 Jalgaon district - density of wooden ploughs in 2011 (Source: Statistical Department Jalgaon)

Sr. No.	Name of Tehsil	Cultivated Area in Hectares	No. of Wooden Ploughs	Density of Wooden Ploughs (Per '1000' Hectares)
1	Chopda	69214	1641	23.71
2	Yawal	56303	1849	32.84
3	Raver	69825	2222	31.82
4	Muktainagar	51230	3286	64.14
5	Bodwad	27347	1449	52.99
6	Bhusawal	29583	1954	66.05
7	Jalgaon	59414	5867	98.75
8	Erondol	45840	529	11.54
9	Dharangaon	45595	2396	52.55
10	Jamner	101501	105	1.03
11	Amalner	73235	3827	52.26
12	Parola	53608	1676	31.26
13	Bhadgaon	35613	1493	41.92
14	Chalisgaon	92129	4763	51.7
15	Pachora	64811	4430	68.35
Total	District	875248	37087	42.37

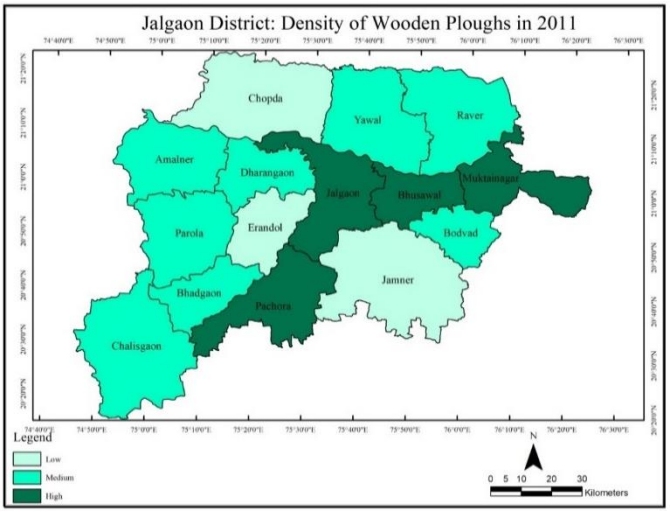

Fig. 1 Jalgaon district: Density of wooden ploughs in 2011

In 2011, other tehsils have density of wooden ploughs ranging 1.03 to 8.75 per sq. thousand hectare cultivated area. The also high densities of wooden ploughs (more than 60 wooden ploughs per sq. thousand hectare cultivated area) are noted in Jalgaon, Pachora, Bhusawal and Muktainagar tehsils. The density ranges between 30 to 60 per Sq. thousand hectare cultivated area observed in Bodwad, Dharangaon, Amalner, Chalisgaon, Bhadgaon, Yawal, Raver and Parola tehsils. While lowest density of wooden ploughs less than 30 per sq. thousand hectare cultivated area detected in Chopda, Erondol and Jamner tehsils because of (i) these are relatively drier parts of the district and wooden scratchers are less suitable for deeper soil tilling; (ii) these are relatively less densely peopled, but more urbanized tehsil of the district and (iii) Finally, medium and large land holding occur more frequent in these areas and wooden ploughs are difficult to use on relatively larger holdings.

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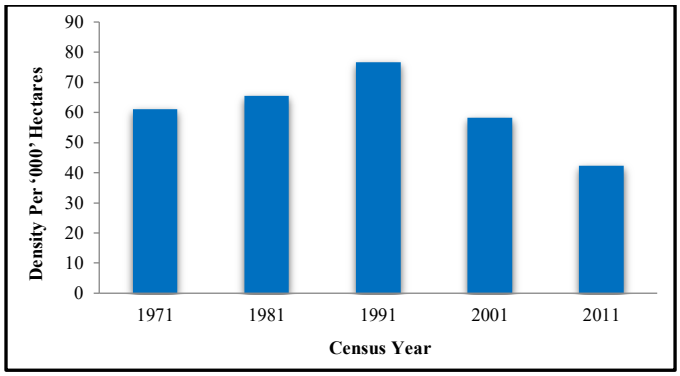

Fig. 2 Jalgaon district: Decadal density of wooden ploughs in 1971-2011

The temporal analysis of wooden ploughs shows (Fig. 2) that the number of wooden ploughs gradually decreases after 1991. In 1971 there were 47000 wooden ploughs, there numbers had increased up to 63000 1991. Density of wooden ploughs also decrease from 61.03 in 1971 to 42.37 in 2011, it means increasing population responsible for the make pressure on agricultural land so farmer looking towards the modern equipment. Wooden ploughs are primitive mechanical techniques used for agricultural cultivation. Today also wooden ploughs are mostly used for cultivation in the remote areas and tribal settlements of the northern and south western part of Jalgaon district because of being there Satpuda ranges. The density of wooden ploughs gradually increases from the more developed areas with medium and large land holdings to the less developed areas of marginal and small operational holdings. This suggest that the correspondents of substitution of wooden ploughs began from the more urbanized areas and is like to expand to other part of the district in future, though force of ignorance conservatism and socio-economic backwardness will continue to restrict their use for some time. It may be noted that the impacts of population pressure may succeed in bringing about technological innovations in Jalgaon district only when the social well-being of the people is allowed to improve.

2.2 Iron Ploughs

Iron ploughs are newer agricultural equipment compare to wooden ploughs. After the half of 19th century developed farmers looking towards the Iron ploughs compare to wooden ploughs because iron ploughs are more durable and intensive equipment than wooden ploughs. Iron ploughs also used maximum in marginal highlands regions. An iron plough is basically a modern version of the wooden plough. Its ploughshares (the part of the plow which is used to plow the field) is made of iron replacing wood from the normal plough thus making it more long lasting than a wooden plough.

Table 2 Jalgaon district: Density of iron ploughs in 2011

S. No.	Name of Tehsil	Cultivated Area in Hectares	No. of Iron Ploughs	Density of Iron Ploughs (Per '1000' Hectares)
1	Chopda	69214	1435	20.73
2	Yawal	56303	1454	25.82
3	Raver	69825	2709	38.80
4	Muktainagar	51230	2326	45.40
5	Bodwad	27347	1257	45.96
6	Bhusawal	29583	1661	56.15
7	Jalgaon	59414	918	15.45
8	Erondol	45840	868	18.94
9	Dharangaon	45595	2107	46.21
10	Jamner	101501	1413	13.92
11	Amalner	73235	1176	16.06
12	Parola	53608	546	10.19
13	Bhadgaon	35613	1401	39.34
14	Chalisgaon	92129	3077	33.40
15	Pachora	64811	2470	38.11
Jalgaon District		875248	24818	28.36

Table 2 shows that highest number of iron ploughs observed in Chalisgaon tahsil by 3077 and lowest iron ploughs are noticed in Parola tahsil with 546. The average density of iron ploughs in Jalgaon district is 28.36 behind per thousand sq. hectare cultivated area. The highest densities of Iron ploughs are noted in Bhusawal Tehsil that is 56.15 per thousand sq. hectare cultivated area. The lowest iron ploughs density is observed in Parola tehsil that is 10.19 per thousand sq. hectare cultivated area. High density of Iron ploughs noted in Bhusawal, Dharangaon, Bodwad and Muktainagar tehsils. Density of Iron ploughs ranges between 20 to 40 per thousand sq. hectare cultivated area recorded in Bhadgaon, Raver, Pachora, Chalisgaon, Yawal and Chopda tehsils. Lowest density of Iron ploughs observed in Erondol, Amalner, Jalgaon, Jamner and Parola tehsils.

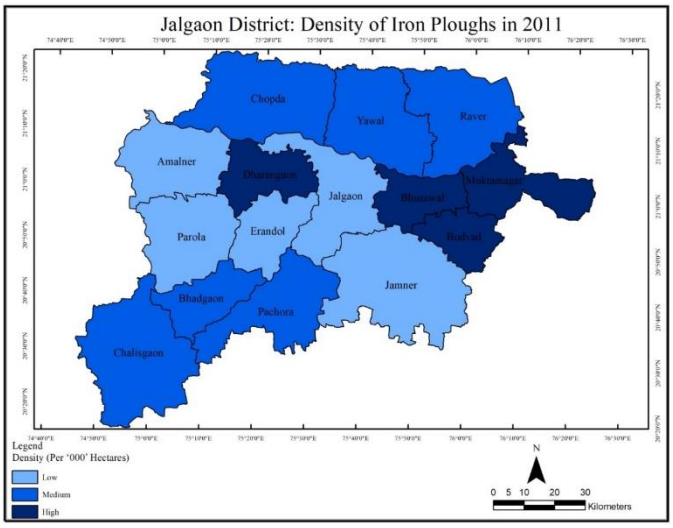

Fig. 3 Jalgaon district: Density of iron ploughs in 2011

The decadal analysis of the iron ploughs shows (Fig. 4) that, the number of iron ploughs also decrease after the 1991. In 1991 there were 49137 iron ploughs and their amount is decease up to 24818 in 2001. it means the used of iron ploughs for the cultivation is also decrease in present period due to the implementation of modern techniques.

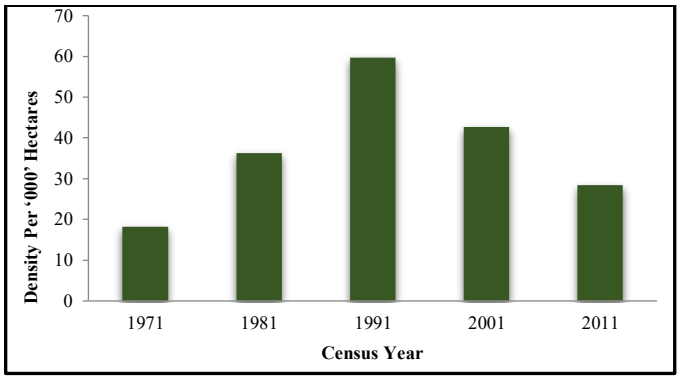

Fig. 4 Jalgaon district: Decadal density of iron ploughs in 1971-2011

4. Conclusion

The analysis of agricultural technology in Jalgaon district from 1971 to 2021 reveals a profound transformation in the regional farming landscape. The shift from primitive, animal-drawn implements to sophisticated, data-driven systems reflect the district's response to rising population pressure and the need for higher productivity.

The Transition of Farm Power: The data indicates a clear decline in traditional implements after 1991. The density of wooden ploughs dropped from 61.03 in 1971 to 42.37 in 2011, while iron ploughs saw a similar downward trend. This confirms that farmers are increasingly substituting animal labour with tractor-drawn machinery to meet the demands of modern intensive cropping.

Geographical Disparity: There remains a stark contrast between the "Plain Zone" and the "Hilly Zone." Remote tribal settlements in the Satpuda and Ajantha ranges still rely on wooden ploughs due to rugged topography and small, fragmented land holdings that make heavy machinery inaccessible or economically unviable.

Technological Leaders: Tehsils like Jalgaon, Bhusawal, and Muktainagar have emerged as leaders in technological adoption. The widespread implementation of drip irrigation has not only saved water but has established Jalgaon as a global hub for banana production.

The Digital Frontier: The recent integration of artificial intelligence (AI) and real-time soil data platforms marks a new era of precision farming. This shift is critical for minimizing environmental risks and optimizing the use of fertilizers and pesticides.

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To ensure sustainable and inclusive agricultural growth in the district, the following measures are suggested:

Custom Hiring Centers (CHCs): To overcome the barrier of small land holdings, the government should promote CHCs where small-scale farmers can rent modern tractors and AI-driven tools at affordable rates.

Infrastructure for Hilly Terrains: Specialized, small-scale power tillers and terrace-friendly machinery should be introduced in the Satpuda and Ajantha regions to reduce the physical drudgery of tribal farmers.

Digital Literacy Programs: As the district moves toward AI and precision farming, intensive training programs are needed to help farmers interpret data-driven insights for irrigation and pest control.

Expansion of Micro-irrigation: While drip irrigation is prevalent in banana belts, it should be expanded to other crops like cotton and pulses to ensure long-term groundwater sustainability.

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