IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Ecological Over-Saturation and the Stocking-Yield Disconnect in Dryland Open-Water Aquaculture: An Empirical Analysis of Yavatmal District, Maharashtra

Kamleshkumar Asaram Tumsare[1] and Praveen Purushottam Joshi [2]
Assistant Professor, Department of Zoology[1]
Professor, Department of Zoology[2]
Amolakchand Mahavidyalaya, Yavatmal (MR), India

Abstract: *This study investigates the biophysical and ecological constraints that limit inland aquaculture productivity in dryland and semi-arid regions, with a focus on the non-linear relationship between fish seed stocking density and actual harvest yield. Utilizing an empirical dataset of 85 water bodies across the 16 talukas of Yavatmal District, Maharashtra, we examine why high stocking rates consistently fail to translate into expected yields. The findings reveal a pervasive "productivity crisis": despite actual stocking rates exceeding optimal limits in 11 of the 16 talukas (reaching up to 188% in Maregaon), the actual fish harvest averages a mere 12.5% of its expected potential yield district-wide [12]. Regression analysis using a quadratic production function confirms a significant scale-dependent disconnect. Excessive fingerling density leads to ecological oversaturation, resource competition, and high mortality rates, which are further exacerbated by extreme summer temperatures (42–45°C) and seasonal hypoxia. Conversely, understocked water bodies, such as the Takali Reservoir, achieve high individual survival and growth rates due to abundant natural forage, highlighting the role of carrying capacity over extensive inputs. The paper advocates for a paradigm shift under national policy frameworks like the Pradhan Mantri Matsya Sampada Yojana (PMMSY)—moving from input-driven state subsidies to scientific, waterbody-specific carrying capacity assessments.*

Keywords: Fish stocking efficiency, Carrying capacity, Productivity crisis, Dryland aquaculture

I. INTRODUCTION

Inland aquaculture in India has transitioned from a localized subsistence activity into a highly commercialized segment of the agrarian economy, providing vital food security and employment for nearly sixteen million primary fishers [8]. Nationally, inland fish production surged from 4.9 lakh tons to 139 lakh tons between 2010-11 and 2023-24, achieving a compound annual growth rate (CAGR) of 8.21% (MFAHD, 2026). This expansion has established India as the second-largest aquaculture producer globally, contributing 8.92% to global fish production [9]. To sustain this growth, the Government of India launched the Pradhan Mantri Matsya Sampada Yojana (PMMSY) in September 2020 with a budget of INR 20,050 crore, aiming to increase national fish production to 22 million metric tons by 2024-25 and enhance average productivity from three to five tons per hectare.

However, translating these national-level targets into regional success remains highly challenging, particularly in dryland, drought-prone environments. In the semi-arid Vidarbha region of Maharashtra, aquaculture development is severely constrained by erratic monsoons, water scarcity, and extreme temperature fluctuations [12]. An empirical assessment of the aquaculture database for Yavatmal District reveals a profound disconnect: while state agencies and local cooperative societies extensively stock water bodies with fingerlings, actual harvests remain remarkably low, averaging just 12.5% of expected yields district-wide [12].

This study examines the biophysical and ecological mechanisms behind this "stocking-yield disconnect". We hypothesize that conventional fisheries management models rely on a flawed assumption of linearity—that increasing fingerling inputs will proportionally increase harvested biomass. In reality, dryland water bodies are subject to strict biological carrying capacity limits, where seasonal shrinkage and thermal stress override simple input increases. By analyzing stocking and yield efficiencies across 85 water bodies in the 16 talukas of Yavatmal, this paper provides an empirical critique of extensive stocking practices and proposes climate-resilient, carrying-capacity-based alternatives

II. MATERIALS AND METHODS

A. Study Area

Yavatmal District, situated in the Vidarbha region of Maharashtra between latitudes 19.42446 N and 20.70409 N and longitudes 77.27932 E and 79.15249 E, features a semi-arid landscape shaped by the Wardha and Penganga river basins. The district experiences erratic monsoon rainfall (averaging 775.2 mm during the South-West monsoon) and severe summer heatwaves, with temperatures frequently reaching 42–45°C [1] [6] [12].

B. Sampling and Data Collection

A stratified random sampling strategy was used to monitor 85 water bodies across the district's 16 talukas. The sample includes 3 major reservoirs (water spread area >1000 Ha), 4 medium reservoirs (501-1000 Ha), and 78 minor water bodies (<200 Ha), including community ponds, tanks, and farm ponds (*shet tale*).

Data collection was carried out across three distinct seasons: pre-monsoon (March–May), monsoon (June–August), and post-monsoon (October–February). Primary data were gathered through geo-tagged field surveys and semi-structured interviews with representatives from 16 primary Fisheries Cooperative Societies (MSS), progressive fish growers, and district fisheries officials. On-site water quality parameters—specifically pH, dissolved oxygen (DO), and ammonia (NH_3)—were monitored using portable analytical testing kits.

C. Taxonomic Identification

The cultivable and wild-capture species composition was inventoried by reviewing catch logs and direct observation. The district's cultured ichthyofauna comprises 16 primary species from 7 orders and 9 families, dominated by Indian Major Carps (IMCs): Rohu (*Labeo rohita*), Catla (*Catla catla*), and Mrigal (*Cirrhinus mrigala*) [12]. It also includes exotic species such as Common Carp (*Cyprinus carpio*), Grass Carp (*Ctenopharyngodon idella*), and the highly invasive Tilapia (*Oreochromis mossambicus*).

D. Analytical Framework and Mathematical Modeling

Optimal stocking standards and expected yields were determined using the Department of Fisheries, Government of Maharashtra guidelines, which utilize a 30x multiplier from stocked fingerlings to expected kilograms of harvested fish. Stocking and yield efficiencies were calculated as follows:

$$\text{Stocking Efficiency} = \left(\frac{\text{Actual Stocking}}{\text{Optimal Stocking}}\right) \times 100$$

$$\text{Yield Efficiency} = \left(\frac{\text{Actual Yield}}{\text{Expected Yield}}\right) \times 100$$

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

To evaluate the relationship between fingerling inputs and actual yields, we construct a quadratic production function to test for diminishing marginal returns:

$$Y_{it} = \beta_0 + \beta_1 S_{it} + \beta_2 S_{it}^2 + \gamma Z_{it} + \epsilon_{it}$$

where Y_{it} represents the actual fish harvest (MT), S_{it} represents the actual stocking density (lakhs of fingerlings), Z_{it} is a vector of environmental control covariates (water spread area in hectares, average seasonal depth), and ϵ_{it} is the random error term.

A one-way Analysis of Variance (ANOVA) was executed to test for statistically significant differences in yield efficiencies across three stocking categories: Understocked (<90%), Optimally Stocked (90%-110%), and Overstocked (>110%).

III. RESULTS

A. Taluka-Wide Database Assessment

The empirical parameters compiled from all 16 administrative subdivisions of Yavatmal District reveal severe imbalances between input stocking rates and actual fish yields.

Table 1 Showing empirical parameters compiled from all Talukas of Yavatmal

Taluka	Surveyed Water Bodies	Water Spread Area (Ha)	Optimal Stocking (Lakhs)	Actual Stocking (Lakhs)	Stocking Efficiency (%)	Expected Yield (MT)	Actual Yield (MT)	Yield Efficiency (%)
Darwha	7	1357	17.060	19.110	108.60%	511.800	38.404	7.50%
Digras	3	2401	15.600	16.225	104.00%	365.250	106.072	29.28%
Pusad	6	7293	43.805	51.210	117.00%	889.650	171.394	19.27%
Ghatanji	4	216	5.350	7.650	143.00%	160.500	26.135	16.28%
Maregaon	2	238	4.065	7.660	188.00%	121.950	27.237	22.33%
Yavatmal	13	592	18.150	12.676	70.00%	544.500	39.483	7.25%
Mahagaon	7	1296	16.470	27.296	165.70%	494.100	76.391	15.46%
Kalamb	9	877	16.350	24.330	149.00%	490.500	44.541	9.08%
Ner	4	1114	18.760	21.800	116.00%	562.800	44.461	7.90%
Umarkhed	6	711	11.885	7.930	67.00%	356.550	25.287	7.09%
Ralegaon	5	181	6.620	2.999	45.00%	198.600	10.004	5.03%
Wani	2	52	2.240	2.400	107.00%	67.200	8.582	12.77%
Babhulgaon	4	5357	47.720	49.145	103.00%	618.000	65.963	10.67%
Jhari-Jamani	2	146	3.660	3.265	89.00%	109.800	4.687	4.27%
Kelapur	3	619	9.650	10.300	107.00%	289.500	49.820	17.20%
Arni	1	150	2.700	4.000	148.00%	81.000	8.044	9.93%

Source: Structured compilation of empirical parameters across all 16 administrative subdivisions in Yavatmal District.

The data reveals that severe overstocking is widespread, with Maregaon stocking at 188%, Mahagaon at 165.7%, and Kalamb at 149% of optimal levels. Yet, these talukas achieve yield efficiencies of only 22.33%, 15.46%, and 9.08%, respectively. Conversely, understocked talukas like Ralegaon (45% stocking) and Umarkhed (67% stocking) also exhibit extremely depressed yield efficiencies of 5.03% and 7.09%. This dual pattern suggests a systemic disruption that cannot be resolved simply by adjusting stocking inputs.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 3, July 2026

Impact Factor: 8.2

B. Regression and ANOVA Analyses

The estimation of the quadratic production function yields a negative and statistically significant second-order stocking coefficient (β_2 = -0.048, $p < 0.05$), confirming a concave, non-linear relationship between fingerling inputs and actual yields. The marginal physical product (MPP) of stocked fingerlings diminishes rapidly and becomes negative when actual stocking rates exceed optimal levels by more than 15%.

The one-way ANOVA indicates no statistically significant difference in yield efficiencies between the "Optimally Stocked" (90%-110%) and "Overstocked" (>110%) water body strata ($F = 1.14$, $p > 0.05$). This statistically demonstrates that over-applying fingerlings does not result in higher yields, indicating that carrying capacity, rather than stocking volume, is the primary constraint.

.

IV DISCUSSION

A. Biophysical Mechanisms of the Stocking-Yield Disconnect

The empirical findings point to a clear ecological carrying capacity constraint. In semi-arid regions like Vidarbha, water bodies undergo drastic seasonal volume reductions. During the dry pre-monsoon season, summer temperatures peaking at 42–45°C warm shallow ponds, accelerating evaporation rates and reducing dissolved oxygen (DO) solubility [12].

When cooperative societies overstock these water bodies—as seen in the Chorkund pond in Ghatanji (246% stocked) or the Satpalli pond in Jhari-Jamani (193% stocked)—the increased biomass demand for oxygen exceeds environmental availability. This triggers biological feedback loops:

1. **Hypoxia**: Dissolved oxygen levels regularly drop to critical levels (1.2-2.4 mg/L) during warm afternoons, far below the optimal threshold (> 5.0 mg/L).
2. **Eutrophication**: High temperatures and agricultural nutrient runoff promote rapid algal blooms, which consume dissolved oxygen as they decay.
3. **Ammonia Toxicity**: High water temperatures and pH levels increase the concentration of un-ionized ammonia (NH_3), which damages fish gills and impairs growth.
4. **Disease Outbreaks**: Warm, hypoxic waters weaken the immune systems of the fish, making them highly susceptible to bacterial pathogens, particularly *Aeromonas hydrophila*, which causes hemorrhagic septicemia.

These factors combine to cause high natural mortality rates and stunted growth, explaining why overstocked talukas like Mahagaon (165.7% stocked) achieve a yield efficiency of only 15.46%.

B. The Understocking Success Paradox

The database also reveals a paradoxical pattern: understocked water bodies often outperform overstocked ones in efficiency. A primary example is the Takali Reservoir in Yavatmal Taluka. Stocked at only 0.5% of its optimal density (0.01 lakhs actual vs. 1.84 lakhs expected), it produced a harvest of 9.25 MT, representing 16.7% of its expected potential yield. This high efficiency is explained by natural carrying capacity dynamics. When stocking densities are kept low, individual fish experience minimal competition for natural zooplankton and benthic food resources. This abundance of natural forage enhances individual survival rates, health, and average weight at harvest. This success highlights the potential of semi-intensive, low-input aquaculture models that leverage natural primary productivity rather than relying on extensive fingerling inputs [12] [13].

C. Scale-Dependent Governance Deficits

The study identifies a consistent scale-efficiency inversion: minor, community-scale water bodies show much higher per-hectare productivity compared to large, state-managed reservoirs [12] [13].

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 3, July 2026
Impact Factor: 8.2

Table 2 Showing scale-efficiency inversion

Water Body Name	Taluka	Water Spread Area (Ha)	Primary Management Structure	Actual Stocking (Lakhs)	Yield Density (MT/Ha)	Yield Efficiency (%)
Minor Ponds & Tanks						
Shivni	Ghatanji	14	Local Cooperative (MSS)	0.70	1.200	102.3%
Pokhari	Mahagaon	17	Local Cooperative (MSS)	0.98	0.466	39.6%
Rampur	Maregaon	15	Local Cooperative (MSS)	0.75	0.270	24.9%
Borda	Wani	27	Local Cooperative (MSS)	1.20	0.252	21.9%
Major Reservoirs						
Bembala	Babhulgaon	5,272	MFDC State Leasing	49.15	0.012	10.6%
Isapur	Pusad	6,660	MFDC State Leasing	35.00	0.028	31.4%
Arunavati	Digras	2,370	MFDC State Leasing	14.60	0.044	43.9%

Source: Compiled from the comparative water body sub-database of Tumsare and Joshi (2025).

This scale-efficiency inversion is rooted in the institutional arrangements of Common-Pool Resource (CPR) management. In major reservoirs like Bembala (5,272 Ha) and Isapur (6,660 Ha), fisheries management operates under extensive leasing systems overseen by the Maharashtra Fisheries Development Corporation (MFDC). Patrolling these vast aquatic surfaces is difficult, which often leads to illegal monofilament net fishing, poaching, and under-reporting of catches. These administrative challenges reduce the reported yield density to nominal rates (0.012 MT/Ha in Bembala and 0.028 MT/Ha in Isapur).

Conversely, community-scale ponds like Shivni (14 Ha) are managed directly by primary Fisheries Cooperative Societies (MSS), whose members belong to traditional fishing communities like the Bhoi, Dhiwar, and Dhimar castes. These communities employ active social monitoring and peer patrolling, which reduces the open-access problem. These institutional arrangements allow Shivni to achieve an exceptional average yield density of 1.200 MT/Ha and a yield efficiency of 102.3%, even under strict adherence to optimal stocking guidelines.

V. POLICY IMPLICATIONS AND TECHNICAL RECOMMENDATIONS

The empirical findings call for a shift in national and state aquaculture policies, particularly under flagships like PMMSY and Maharashtra's Blue Revolution 2.0.

To optimize production and ensure sustainable development, the following interventions are recommended:

1. **Adopt Flexible Stocking Protocols**: Replace rigid stocking guidelines based solely on surface area with adaptive, carrying-capacity-based standards. Local fisheries departments should calibrate seasonal stocking densities based on water depth, primary productivity, and key water quality parameters (such as pH, DO, and ammonia).
2. **Support Localized Seed-Rearing Networks**: Transition from centralized seed production to decentralized, community-managed nurseries. Supporting women-led self-help groups (SHGs)—such as the Eklara Matsyabij Kendra in Ralegaon—can establish localized rearing units, reduce transportation stress and mortality, and promote socio-economic equity.
3. **Establish Hybrid Co-Management Systems**: Grant spatial management and enforcement rights to local cooperatives (MSS) within state-managed reservoirs. This collaborative approach can lower monitoring costs, reduce poaching, and improve catch reporting.
4. **Develop Disease-Monitoring and Mitigation Frameworks**: Implement regular water quality monitoring and establish veterinary support for quick disease diagnosis to protect fishers against production crashes.

5. **Utilize Underactive Assets**: Prioritize funding and technical support to utilize underactive water bodies, such as the Digdoh Reservoir in Ralegaon (51 Ha) and the Pachpahur Reservoir in Jhari-Jamani (106 Ha), to expand regional production.

VI. CONCLUSION

The comprehensive analysis of Yavatmal District's aquaculture database highlights a critical gap between input-driven policies and local ecological realities in dryland environments. Widespread overstocking fails to yield proportional returns, with the district operating at an average of just 12.5% of its potential yield. This disconnect is driven by ecological carrying capacity constraints, seasonal water quality degradation, and scale-dependent governance challenges.

To promote sustainable rural development through pisciculture, policy frameworks like PMMSY must move beyond simple stocking targets and adopt a science-intensive, carrying-capacity-based approach. Calibrating stocking densities to local biophysical limits, supporting community-scale cooperatives, and utilizing untapped aquatic resources can transform the sector into a resilient engine of economic growth, food security, and environmental stewardship

REFERENCES

1. Atkulwar, T., et al. (2024). Fish species diversity in reservoirs of Yavatmal District, Maharashtra. *Indian Journal of Fisheries*, 71(1), 45-52.
2. Avnimelech, Y. (2012). *Biofloc Technology: A Practical Guide Book*. World Aquaculture Society.
3. Bhendarkar, M. P., Brahmane, M. P., & Singh, N. P. (2018). Farm pond-based aquaculture models for doubling farmers' income. *Shetkari*, 44-47.
4. Boyd, C. E., & Tucker, C. S. (2012). *Pond Aquaculture Water Quality Management*. Springer Science & Business Media.
5. Deosthale, S., et al. (2012). Fish fauna of Bembala Reservoir, Yavatmal District, Maharashtra, India. *Multilogic in Science*, 2(2), 58-60.
6. Department of Fisheries, Government of Maharashtra. (2021). *Amravati Division Fish Production and Water Body Registry*.
7. Food and Agriculture Organization (FAO). (2020). *The State of World Fisheries and Aquaculture 2020*. Rome.
8. Jayasankar, P. (2018). Present status of freshwater aquaculture in India - A review. *Indian Journal of Fisheries,* 65(4), 157-166
9. Ministry of Fisheries, Animal Husbandry & Dairying (2026)
10. Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press.
11. Pawar, S. K. (2017). Community-led stock enhancement in Isapur Reservoir, Yavatmal. *Journal of Environmental Management*, 114, 112-119.
12. Tumsare, K. A., & Joshi, P. P. (2025). Pisciculture: Diversity of reared fishes in Yavatmal District of Maharashtra. *Adarsha Journal of Research & Evaluation*, 690-692.
13. Tumsare, K. A., & Joshi, P. P. (2025). The Productivity Paradox in Inland Pisciculture: A Comparative Analysis of Stocking Efficiency, Yield Disparities, and Management Practices in High-Performing (Pusad, Digras) versus Low-Performing (Jhari-Jamani, Wani) Talukas of Yavatmal District. Proceedings of NZCWWET-2025, 153-160.

DOI: 10.48175/IJARSCT-37857