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# SUSTAINABLE TURFGRASS SPECIES SELECTION AND MANAGEMENT FOR SPORTS FIELDS UNDER INDIAN CONDITIONS: SCIENTIFIC PERFORMANCE, MAINTENANCE ECONOMICS AND BUSINESS OPPORTUNITIES

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## ABSTRACT
Growing organized sport and public sporting infrastructure in India is creating greater demand for environmentally sustainable natural playing surfaces. Species choice has a range of impacts on traffic recovery from a given surface, stability of the surface, demand for water, mowing frequency, disease risk, and life cycle cost of the surface. This research/article is aimed at creating a decision making framework for turf in India using the recently published peer reviewed turfgrass studies, climate and sports policy related to India, and turfgrass related data to build a multi-criteria decision analysis and a cost model related to field construction of 8,000 m² in India. Hybrid and seeded bermudagrasses provided the best solution for hot, dry, and sub tropical regions that experience heavy traffic. Zoysiagrass is recommended for fields that experience traffic but will remain mostly unoccupied. In addition, Zoysiagrass is recommended for fields that will experience some shade. For coastal fields using poor quality irrigation, Seashore Paspalum is recommended. Year round, Ryegrass is not recommended for most of India, however, it is recommended for winter overseeding in the northern and elevated regions of India. The modeled sustainable precision-turf system decreased cost of operating a field for one year from ₹30.4 lakh to ₹22.8 lakh due to reduced irrigation, reduced fertilizers, and improved traffic rotation. At an 8% discount rate it also provided the best value among the systems compared for high quality playing fields over a ten year period. The other systems also provided many business opportunities from contracting turf to providing precision irrigation.
The main finding is that, in contrast to the current singular approach to recommending grasses, sustainable sports turf in India needs regional species zoning, performance-based procurement, auditable maintenance plans and professional field management.

**KEYWORDS:** Sports turfgrass; Bermudagrass; Zoysiagrass; Seashore paspalum; Sustainable turf management; Precision irrigation; Lifecycle cost analysis;

## INTRODUCTION
A sports field is a biological and engineered surface. To create a quality sports surface, one combines plant genetics, rootzone construction, drainage, irrigation, mowing, nutrition, traffic scheduling and maintenance team skill. A field can be visually appealing and green, yet traction, hardness, surface evenness and divot stability can make it an unsafe playing surface. On the other hand, a field can be functional with a firm rootzone, a thick grass canopy, and active recovery from wear, even if it has uneven color. Therefore, the goal of sustainable turfgrass management can be defined by playing performance and resource efficiency in the long term, rather than by turf color.
The Indian operating environment makes this goal of sustainable turfgrass management particularly important. Fields can be exposed to a wide range of challenges including over 40 degree C heat, monsoon rains, long droughts, saline coast waters, urban soil compaction, dust, limited funds, irregular maintenance schedules, and limited time between scheduled events. The India Meteorological Department (IMD) forecast for 2025 predicts 2025 will be the start of a period of high rainfall, while the 2016-2025 decade is projected to be the hottest in the subcontinent. These forecasted values mask large scale regional variations. Planning for the coastal states will need to take into account high temperatures, high humidity and saline waters, while the highland venues will require cool season (IMD, 2026).
The public sector is also burgeoning the sports economy. In the Union Budget 2026-2027, the allocation to the Ministry of Youth Affairs and Sports was increased to ₹4,479.88 crores, and ₹924.35 crores was allocated to Khelo India. The Khelo Bharat Niti 2025 also talks about the sports economy with reference to the development of the economy,

employment, and manufacturing and service-related activity, as well as infrastructure for hosting events (Ministry of Youth Affairs and Sports [MYAS], 2025a; Press Information Bureau [PIB], 2026). Each new or upgraded outdoor sports facility generates sustainable demand for the establishment of the sports field, as well as demand for irrigation, equipment, and agronomy, and for conducting turf field testing, and maintenance.
Indian sports turf decisions are made with limited evidence, and while most of the research on sports turf is for hot regions, it is important to understand that there are many differences that will impact the outcome, such as the quality of irrigation and drainage during the monsoon, the nature of the workforce, the turf species used, and the varying dormancy periods. The turf and sports field research in India needs to be integrated to develop turf management economically and operationally. This will require the ability to differentiate between real field observations and model based assumptions because there are currently no databases in India that provide a cost estimate for the maintenance of various turf species for sports fields, the water requirement, and the quality of the field for sports activities.
The objectives of this paper are to: (a) Analyze primary turfgrass species for sports-field use in India. (b) Relate turfgrass species to climatic and operational zones. (c) Establish environmentally-sustainable practices for turf management of water, nutrients, mowing, traffic, and plant health. (d) Analyze and predict the annual and lifecycle costs of turf maintenance with a scenario model that explains all assumptions. (e) Create and assess value-adding business models for the Indian sports-turf market.

## 2. Research Questions and Contribution

This analysis seeks to answer four primary questions. Which warm-season and cool-season turfgrasses best combine the qualities of traffic tolerance and recovery and adaptability to different environments and lesser management needs in the Indian sub-continent? Second, what species should be used in the different hot-dry, hot-humid, monsoonal subtropical and cool-highland zones? Third, what management practices reduce water and maintenance costs the most while preserving the functional surface? Finally, what scope exists for nurseries, contractors, technology providers, consultants and facilities to pursue commercially viable opportunities?
The contribution is unique in that it provides an integrated decision model instead of a traditional descriptive review. Plant-performance research of the last few years has been translated to evidence-normalized trait scores with a zone-specific custom weighting for India. These recommendations have been linked to a 10-year cost model and an opportunity portfolio. This design allows stadium authorities, universities, municipal and private sports bodies, cricket and football clubs, landscape contractors, and investors to use the findings.

## 3. Indian Climatic, Resource and Sports-Infrastructure Context

### 3.1 Climate variability and field stress

You cannot consider India a one climate zone for turfgrass. There are a number of unique growing conditions. Extremely hot and dry areas favor turfgrass species that are deep rooting, use less water, and are resilient to heat. In turfgrass growing areas of hot and humid climates, turfgrass must have the ability to withstand prolonged periods where the grass leaves are wet, a lot of diseases, high salinity, and whether or not the grass gets waterlogged. In the areas of India that have a Subtropical climate and a monsoonal season, turfgrass must have a lot of recovery in the summer, good drainage, and a plan for winter, as warm-season turfgrass may go dormant.
The summer monsoons pose the biggest challenge for turfgrass management in India. Even though summer monsoons may reduce the need for turfgrass irrigation, the intense rains of the monsoon season can create fields that become unusable, erode the turfgrass root system, wash away nutrients, and create a lack of oxygen in the soil. The biggest challenge in choosing turfgrass in India may be balancing drought with too much water.

### 3.2 Water scarcity, quality and reuse

The Indian sports turf industry has to deal with irrigation costs likely being the highest variable cost in the industry. The economic and environmental costs of irrigation depend on source and type of irrigation, pumping elevation, price of irrigation, water quality and irrigation distribution uniformity. Unless fresh potable water is required as the preferred source, it should not be assumed to be the default option where treated wastewater, stormwater, or other blended marginal waters can be used safely. Salinity, along with drainage and leaching, should not be an issue with the management of soil and turf if Seashore paspalum, Bermudagrass or Zoysia grass are used. Moreover, monitoring sodium and salinity are necessary since soil can destricate regardless of turf being green (Liu et al., 2023).
Irrigation also needs to consider spatial variability. If uniform irrigation is used on a field with spatial variability, wet zones will be over watered while dry zones will be under watered. The use of soil moisture mapping, E.C. mapping, and periodic drone and thermal imaging can be used to help with irrigation zoning. It has been noted in research covering the etiology of large turf areas that irrigation zoning is best accomplished by the use of patterns of soil moisture and that zoning should be flexible and revisited over time rather than being permanently set (Kerry et al., 2023, 2024).

### 3.3 Growth of the sports economy

The policy direction allows for a more extensive addressable market for natural sports turf services. Public initiatives are supporting the development of training facilities and competition venues and increasing grassroots participation. Simultaneously, playable green spaces are being developed through investments by professional sports, schools, universities, private real estate (townships), and private sports academies. The applicable commercial market is much more extensive than just grass supply. It includes the design of fields and rootzone and includes drainage, irrigation, and turf care equipment, diagnostics, and renovation, as well as staffing, data services, and service-level agreements.

Most likely the greatest potential opportunity is in performance responsibility. A sports field provided as a construction element can fail after the handover because plant establishment and turf maintenance are the responsibility of different parties. The use of design-build-maintain contracts, coupled with warranties for objective surface indicators and multi-year maintenance agreements, can create the necessary alignment of responsibilities across the lifecycle of the asset.

## 4. MATERIALS AND METHODS

### 4.1 Evidence synthesis and inclusion logic

The study employed a methodical approach to evidence synthesis with regards to publications and official documents between 2019 and July 2026. Sources were chosen for synthesis when they described sport-turf traffic, drought, irrigation, salinity, remote sensing, hybrid systems, lifecycle impacts, field management problems, or Indian sports and climate policies. Foundational literature older than seven years was not cited because of the evidence window, but the authors of those studies read and interpreted the older literature. Established agronomic principles were interpreted through recent studies and reviews.

The evidence base consists of three different source types. The first type consists of Indian official observations and allocations, including the 2025 climate report, the Ministry of Youth Affairs and Sports annual report, the Khelo Bharat Niti 2025, and the 2026–2027 sports budget. The second type consists of peer-reviewed turfgrass studies, and the third type consists of the modeled outputs developed in this study. Modeled values were not presented as observed national statistics.

**Table 1. Data architecture and analytical role**

| Layer | Source / basis | Use in analysis |
|---|---|---|
| Official Indian context data | IMD 2025 climate statement; MYAS 2024–2025 annual report; Khelo Bharat Niti 2025; Union Budget 2026–2027 | Defines current climate pressure and sports-infrastructure demand |
| Peer-reviewed biological evidence | Traffic, drought, salinity, irrigation, hybrid reinforcement, remote sensing and management studies (2020–2025) | Supports species trait scores and management recommendations |
| Evidence-normalised MCDA | Seven traits scored from 1 (weak) to 5 (strong), then weighted by four Indian operating zones | Ranks relative suitability; does not claim cultivar trial results in India |
| Engineering cost scenario | 8,000 m² field; 2025 Indian rupees; annual operating items, capital cost and scheduled renewal | Compares systems consistently where a national cost database is unavailable |
| Business opportunity assessment | Attractiveness, entry barrier, sustainability value and indicative revenue scale scored from 1 to 5 | Prioritises commercially actionable segments |

This table illustrates the main methodological boundary. Official data are used to observe climate and budget values. Species and management conclusions result from evidence-based synthesis and cost and business values are decision scenarios. This dissent enhances reproducibility and avoids false precision.

### 4.2 Multi-criteria decision analysis

Six species or use-types were assessed: hybrid bermudagrass, common/seeded bermudagrass, zoysiagrass, seashore paspalum, kikuyugrass and perennial ryegrass. The ryegrass is for seasonal overseeding or use in cool zones and is not intended for use as a permanent cover. Seven aspects were evaluated based on a five-point scale: traffic tolerance, recovery rate, heat tolerance, drought tolerance, salinity tolerance, shade tolerance, and low-input potential. The scores are based on the consensus in the recent experimental and review literature (Katuwal et al., 2022; Liu et al., 2023; Sancar et al., 2023; Singh et al., 2024a, 2024b).

A weighted score was calculated for each operating zone. For species i, this score is referred to as $S_i$, and is calculated by $S_i = \Sigma(w_j x_{ij})$. In this equation, $w_j$ refers to the zone-specific weight of criterion j, and $x_{ij}$ is the evidence-normalised score. The sum of the weights is 1. For the hot-dry zones, weights of criterion j that represent drought and heat are assigned greater importance. For the coastal zones, criterion j related to salinity is assigned greater importance. For the monsoonal zones, greater importance is provided to criterion j related to the recovery of traffic, as well as to low-input resilience. In the cool-highland zones, criterion j related to low-input potential and shade are assigned greater importance in comparison to heat.

### 4.3 Maintenance economics

The cost model estimates a 8,000 m² multi-sport field and presents costs in future Indian rupees for 2025. Three natural turf systems were compared: traditional natural turf, sustainable precision turf, and hybrid natural turf. As a lifecycle cost benchmark, an artificial turf system was included as a comparison procurement reference due to the turf system preference of many asset owners. The main cost components are labor, mowing, irrigation, nutritive and cultivation inputs, pest control, and repair and monitoring. Rootzone, irrigation, and construction works are capital costs. Scheduled renewal includes midlife repair for the sustainable turf system, renewal of turf reinforcements for hybrid natural turf, and carpet replacement at year nine of the lifespan for the artificial benchmark.

The model has a discount rate of 8% over a ten year period. It is meant to provide comparative decision support and not to establish tender costs. Local costs must be adjusted prior to procurement because there is a wide range of variability in costs for water, labor, soil, transport, equipment, and drainage in different cities in India.

## 5. Scientific Performance of Candidate Turfgrass Species

### 5.1 Hybrid bermudagrass

Across most warm Indian regions, Hybrid Bermudagrass is the leading option for elite, high-traffic fields. Hybrid Bermudagrass has excellent lateral recovery and divot repair capability and has a dense low canopy. More recent traffic studies have shown a lot of variation between different cultivars. Therefore, when procuring this grass, a tested cultivar or a certified planting source should be used rather than the broad term "Bermuda grass." (Sancar et al. 2023; Singh et al. 2024a, 2024b)

Bermudagrass is sensitive to shade, is winter dormant in Northern India, and prefers high fertility to perform at its best. These traits can be of little concern if venues have full sunlight, skilled labor, and foresight into seasonal grass management. For stadiums with indirect light or roof shade, grass management to mitigate shade or using Zoysiagrass in sure the low wear shaded zones may be the best options.

### 5.2 Seeded or common bermudagrass

Common and seeded Bermudagrass have low establishment costs and good drought resistance, making them ideal for use at public facilities, schools, Parks and other regional centers, especially in large area applications. Recovery is fairly quick though uniformity and fineness are generally less than top tier hybrids.

The logistics become less of a challenge with seeds. They are easier to store and transport than sod or sprigs, meaning a wider area can be covered. The management risk involves visible and genetic variability when using uncertified or locally sourced seeds. To mitigate this risk, a seed specification including cultivar, purity, germination, sowing rate and criteria for acceptance post establishment should be drafted.

### 5.3 Zoysiagrass

Foliar grass needs little upkeep and offers a visually polished surface. After establishment, it needs less nitrogen and fewer mowings. It serves well for low and mid traffic athletic fields, school grounds, practice fields, and the breaks of fields that are mostly shaded. It helps reduce emergence of weeds and it uses moisture efficiently through drought if a cultivator plans the schedule with deficit irrigation.

It can take some time for foliar grass to heal from drought or heavy traffic. Zoysiagrass isn't a good choice for fields with continuous heavy traffic. The production of sod and development time are important for the cost of fields. Recent studies (Braun, 2025) have shown that the production of zoysia sod helped the selection of the cultivation method, choice of sod, and the market.

### 5.4 Seashore paspalum

Seashore paspalum provides an option for sites along the coast and for those planning to use brackish or treated irrigation water of the future. Seashore paspalum can create a quality turf surface that is dense and that many other turf grasses would struggle to establish and maintain in the presence of saline water. This turfgrass is well suited for the coastal areas of India and for urban developments where the use of potable water is limited.

Seashore paspalum is not a no-maintenance turf option. Salts will still need to be leached from the rootzone, and the sodium hazard will need to be addressed. The risk of turf diseases may also be increased due to the wet, humid environment that will be produced by a dense turf canopy. For these reasons, seashore paspalum should be considered as one of the components of a water-quality and drainage management system.

### 5.5 Kikuyugrass and perennial ryegrass

The Kikuyugrass has aggressive growth and a strong recovery rate. This may lead to problems as Kikuyugrass can cause thatch and will encroach upon areas. It will also require frequent mowing. While Kikuyugrass may be used in a few selected sites on the highlands, it is not recommended as a national default as it will require local trials to estimate its effect. Kikuyugrass is only useful in low budget sites with high usage.

Perennial Ryegrass can survive in cooler temperatures and has a very quick germination rate. This variety can also retain a good appearance during the winter making it suitable for dormant Grass in cooler climates. Perennial Ryegrass does retain some issues. There are very few places in India where it can survive year long, and in the spring it will, inhibit the growth of Bermudagrass. For these reasons, it is only for seasonal use.

**Table 2. Comparative performance profile of major turfgrass options**

| Species / use-type | Traffic | Recovery | Heat | Drought | Salinity | Shade | Low input | Best Indian role |
|---|---|---|---|---|---|---|---|---|
| Hybrid bermudagrass | 5 | 5 | 5 | 4 | 3 | 2 | 3 | Elite football, cricket outfields, high-use stadiums |
| Seeded/common bermudagrass | 4 | 5 | 5 | 5 | 3 | 2 | 4 | Schools, universities, municipal and regional grounds |
| Zoysiagrass | 4 | 2 | 5 | 4 | 3 | 4 | 5 | Moderate-use |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | fields, shaded margins, low-input institutions |
| Seashore paspalum | 4 | 4 | 5 | 3 | 5 | 3 | 3 | Coastal/saline or marginal-water fields |
| Kikuyugrass | 4 | 5 | 4 | 4 | 2 | 3 | 3 | Mild highlands and aggressive-recovery sites |
| Perennial ryegrass | 3 | 2 | 1 | 2 | 2 | 4 | 2 | Winter overseeding or cool highland seasonal use |

**Interpretation:** Hybrid Bermudagrass is best for an all–around grass with traffic tolerance, fast recovery and heat resistance. Common Bermudagrass is best for drought recovery and has the lowest establishment cost. Zoysiagrass is best for low–input and shade tolerance but cannot be relied upon for quick recovery. Seashore Paspalum has salt tolerance and is in a class by itself. Ryegrass has a low heat tolerance so it can only be considered a seasonal option.

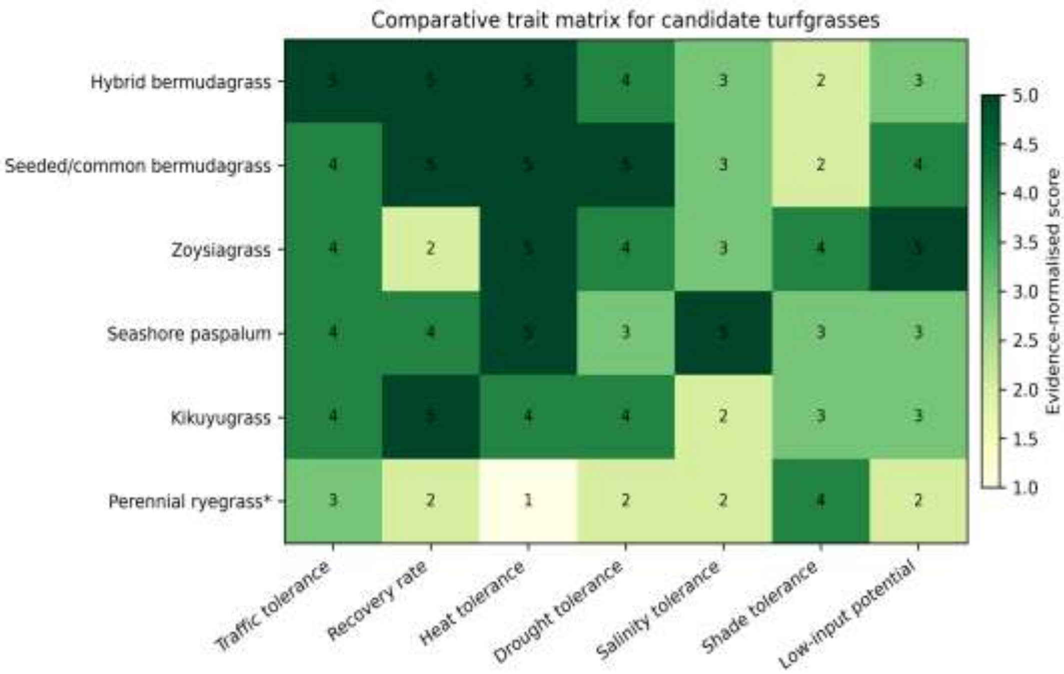


**Figure 1. Comparative trait matrix for candidate turfgrasses**

*Source: Author's evidence normalization according to Katuwal et al. (2022), Liu et al. (2023), Sancar et al. (2023), and Singh et al. (2024a, 2024b).*

**Interpretation**: No species dominates all characteristics. This is the primary outcome of selection. The right choice depends on the type of site stress that is the most costly or difficult to control. With regard to coastal salinity, paspalum is the most suitable species; for low input goals, zoysiagrass is the most suitable; and for intense use of sports traffic, bermudagrass is the most suitable.

**6. Zone-Specific Selection under Indian Conditions**

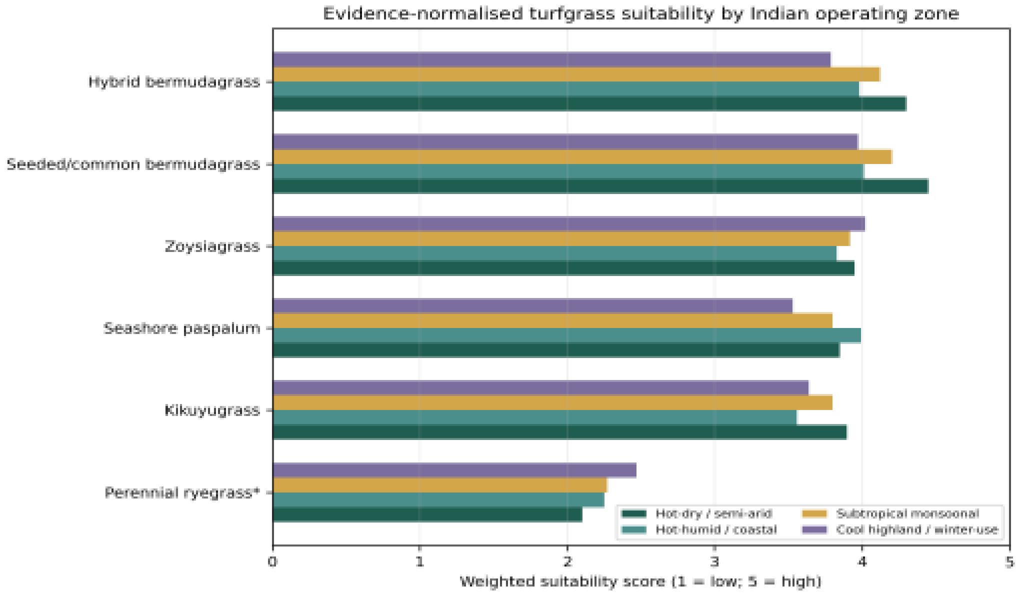


**Figure 2. Evidence-normalised turfgrass suitability by Indian operating zone**

*Source: The author's multi-criteria decision analysis shows scores for Indian cultivars, but those scores do not reflect direct observations from the Indian cultivar trials.*

**Interpretation:** Bermudagrasses are the highest ranked for the hot-dry or subtropical zones due to the close preference for recovery and resistance to heat. Recovery of Seashore paspalum is significant in coastal zones due to the high preference for salinity. Zoysiagrass is ranked in all warm zones, particularly in the zones of the greatest input reduction. Ryegrass is ranked more positively in the cool-highland zones or in the winter zones of use.

**Table 3. Recommended species strategy by Indian operating zone**

| Operating zone | Primary species strategy | Management priorities | Avoid |
|---|---|---|---|
| Hot-dry / semi-arid (Rajasthan, interior Gujarat, rain-shadow Deccan) | Seeded/common bermudagrass; drought-efficient hybrid bermudagrass | Deep rooting, deficit irrigation, wetting-agent trials, low-N spoon feeding, wind-aware irrigation | Over-irrigating for colour; shallow frequent watering; high-salt fertiliser programmes |
| Hot-humid / coastal (Kerala, Goa, coastal Karnataka, Tamil Nadu, Odisha, West Bengal coast) | Seashore paspalum where salinity is material; hybrid bermudagrass where fresh water and sun are available | Drainage, salinity/EC monitoring, air movement, disease forecasting, treated-water controls | Assuming salinity tolerance removes drainage and leaching requirements |
| Subtropical monsoonal (Delhi NCR, Uttar Pradesh, Bihar, Madhya Pradesh, Punjab/Haryana plains) | Hybrid bermudagrass; seeded bermudagrass for budget fields; optional winter rye overseed | Monsoon drainage, summer recovery, winter dormancy plan, traffic rotation, transition management | Permanent ryegrass in hot lowlands; poor drainage; late-season heavy N |
| Cool highland / mild plateau (Himalayan venues, selected hill stations and higher elevations) | Perennial ryegrass or cool season mix where summer temperatures permit; kikuyu or bermuda in mild warm highlands | Local trial plots, frost and summer-heat monitoring, seasonal species transition | Selecting from national averages without site temperature and frost data |
| Shaded or partially roofed stadium zones | Shade-tolerant zoysiagrass for moderate wear; targeted hybrid systems or grow-light support for elite fields | Daily light integral mapping, reduced N, reduced irrigation in shade, traffic exclusion | Using high-recovery bermuda in persistent low light without mitigation |

Interpretation: The selection unit should be the field microclimate rather than the state. A stadium bowl can form an internal city microclimate of cool, humid air in an otherwise hot and dry city. The salinity of treated waters can also induce physiological salt stress in otherwise coastal freshwater climates. Consequently, the procurement process should initiate with a site diagnosis of the field's light, soil, water, drainage, field use, and maintenance capacity.

## 7. Sustainable Management Framework

### 7.1 Rootzone, drainage and establishment

A sustainable field starts below the canopy. The rootzone should balance drainage and moisture retention, resist compaction, and maintain surface stability. With grading, surface drainage, and cultivation, lower-budget fields can retain native heavy soils, while engineered sand-based or sand-capped systems are used in elite fields. Hejl et al. (2022) showed that artificial intelligence irrigation can maintain adequate turf in sand-capped systems, which supports the use of forecasted evapotranspiration and soil moisture as opposed to a calendar-based irrigation system.

The method of establishment should depend on the time of opening and available budget. Although sodding is the fastest method of opening a field and preventing surface erosion, it is the most expensive. Sprigging is less costly and can produce a vegetative cover of either bermudagrass or paspalum, provided there is good irrigation and weed control. Seeding is suitable for seeded covers of either bermudagrass or ryegrass. Grounds should be accepted for uniform cover, root development, even surface, and traction, as opposed to simply meeting the visual handover standard of accomplishing turf cover.

### 7.2 Precision irrigation and water quality

Irrigation should offset some evapotranspiration and be adjusted for moisture in the rootzone, rainfall, and field use. Generally, irrigation that is deep and infrequent promotes deeper rooting. Syringing is normally used for quick irrigation with the purpose of heat relief or plant establishment. Often, before the use of advanced technology, savings can be realized at the design and regulatory stages through head-to-head sprinkler coverage, pressure regulation, catch-can audits and leak control.

When cost of water is high or when there is high spatial variability, precision systems are of high value. The integration of soil moisture sensors, weather information, flow measurement devices, control of flow and level valves, electrical conductivity measurement and drone imaging can establish management zones. Kerry et al. (2024) showed that ECa and drone data are able to capture important soil moisture data for short intervals and, therefore, periodic recalibration of this data is more justified than one time mapping. A comprehensive evaluation of automated irrigation systems identified the quality of sensors and cyber security issues as the main obstacles to implementation (Nsoh et al., 2024).

### 7.3 Mowing, nutrition and cultivation

Mowing should follow the one-third rule and the rate of growth, not a scheduled weekly mow. Fine elite surfaces require mowing by reel while utility fields can use rotary mowers. Stress on turf can be caused by improper height, dull blades, and excessive clippings. Frequent mowing to a lower height may have the desired effect of faster turf and a better visual effect, but may have an adverse effect of shallower roots which may increase the need for irrigation and make turf more susceptible to turf diseases. Height of cut should be considered a variable to turf performance, as Sancar et al. (2023) showed how cutting height can affect a cultivar's tolerance to traffic.

While Biostimulants may support turf performance by improving turf resilience to stress and altering the thatch layer, field evidence is limited and they should never substitute the core fertility practices, proper irrigation, and cultivation. They may support turf performance but should never substitute irrigation or other core practices of turf management (Bosi et al., 2023).

Timely traffic management by routing, topdressing, vertical mowing, and aeration by solid-tine or hollow- tine greatly reduces compaction. Heavy machinery during turf saturation may cause more damage than benefit.

### 7.4 Traffic, scheduling and surface testing

Traffic control is the most cost effective strategy to protect your fields. Reinforcement or rotation of warm-up areas, goal mouths, cricket run-ups, team entry lanes and officials pathways is advised. Concentrated wear is lessened by the use of portable goals, training grids and temporary field protection. Recovery days should be scheduled on a venue calendar indicating the planned use of the field, rather than placing it on the calendar for maintenance at their discretion.

Objective testing must include surface hardness, traction, rotational resistance, evenness, moisture, infiltration, and percentage cover. According to the findings of Yue et al. (2024) field management is primarily restricted by budget, scheduling and weather considerations. The primary objective of performance reporting is to document these considerations to management, thereby alleviating the burden of funding maintenance.

### 7.5 Integrated pest management and circular inputs

The foundation of integrated pest management is proper identification of the pest species involved, combined with attention to site drainage, mowing, and nutrition. Instead of calendar-based pesticide programs, the emphasis should be on scouting and treatment based on action thresholds. Specific Indian environmental factors should be considered, including leaf wetness, over-fertilization, and airflow. Establishing a dense turf canopy is a more cost-effective way of weed control than applying herbicides repeatedly.

Examples of circular management in sports turf include: topdressing with compost, treatment of wastewater, and storage of stormwater; as well as the use of electric mowers and clipping returns (where disease risk is controlled), and the recovery and reuse of rootzone materials during turf renovation. True circular management requires sustainability verified through substituted inputs, not through labeling materials as “recycled.”

**Table 4. Indicative annual management calendar for warm-season Indian sports turf.**

| Period | Primary operations | Sustainability control |
|---|---|---|
| January–February | Dormancy management in north; light mowing | Avoid heavy nitrogen on dormant |

| | | |
|---|---|---|
| | in warm south; soil testing; irrigation-system audit | bermuda; plan spring renovation |
| March–April | Spring green-up; aeration where recovery begins; pre-season fertilisation; repair thin areas | Transition ryegrass before it suppresses bermuda |
| May–June | Peak heat irrigation control; frequent mowing; traffic protection; salinity monitoring | Use moisture data; irrigate during low-wind hours |
| July–September | Monsoon drainage, disease scouting, reduced irrigation, surface repair between events | Avoid heavy machinery on saturated soil; protect outlets |
| October–November | Recovery fertilisation; cultivation; overseed only where winter use justifies it | Do not overseed automatically; compare operational benefit with transition cost |
| December | Winter play management; reduced irrigation; machinery servicing; annual performance review | Use surface testing to set next-year budget |

**Interpretation:** The calendar has flexibility, based on the climate rather than a rigid systems approach. While southern coastal venues are likely to be actively growing during the winter months, in the north, bermudagrass will be dormant. The guiding principle is to schedule disruptive activities during the period of high recovery potential and to minimize management inputs during low growth periods.

**8. Maintenance Economics and Lifecycle Value**

**Table 5. Estimated Annual Operating Costs for an 8,000 m² Field (₹ lakh, 2025-price scenario)**

| Cost item | Conventional natural turf | Sustainable precision turf | High-performance hybrid natural |
|---|---|---|---|
| Labour and supervision | 7.2 | 6.6 | 8.2 |
| Irrigation water and energy | 5.8 | 3.6 | 4.6 |
| Mowing, fuel and machinery upkeep | 4.8 | 3.9 | 5.0 |
| Fertiliser and soil amendments | 3.8 | 2.7 | 4.0 |
| Aeration, topdressing and drainage care | 3.2 | 2.9 | 4.2 |
| Pest/weed/disease management | 2.1 | 1.2 | 1.7 |
| Repair, divoting and seasonal transition | 2.7 | 1.4 | 2.8 |
| Monitoring, testing and administration | 0.8 | 0.5 | 1.0 |
| Total | 30.4 | 22.8 | 31.5 |

**Interpretation:** The sustainable precision system reduces costs by ₹7.6 lakh per year, a 25% reduction, compared to the conventional scenario. Most savings occur in irrigation, mowing, nutrition, chemical treatments, and repairs. While many costs do decrease in the sustainable turf scenario, inspection and management require some labor for moisture control and prevention. Sustainable turf does not mean no maintenance; it simply means we will spend less on recovery efforts and more on planned management.

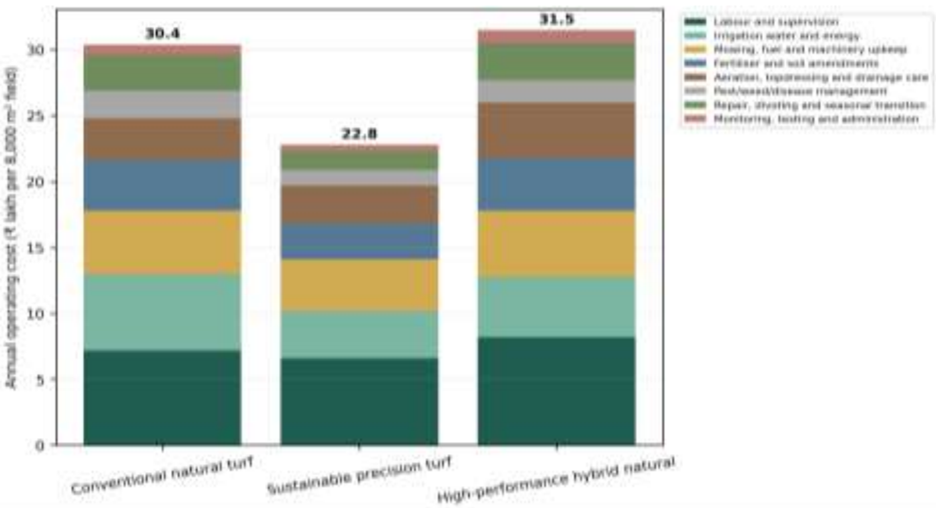


**Figure 3. Modelled annual maintenance cost structure**

*Source: Author's design for an engineering solution to an 8,000 m² field. Values should be substituted with local tender rates prior to procurement.*

**Interpretation.** The largest cost in all natural systems will always be labour. The system which has the most sustainable approach does not have a single major cost reduction but several smaller reductions. Natural turf systems rely on more cultivation, machinery and labour due to the more intensive management of turf systems for events.

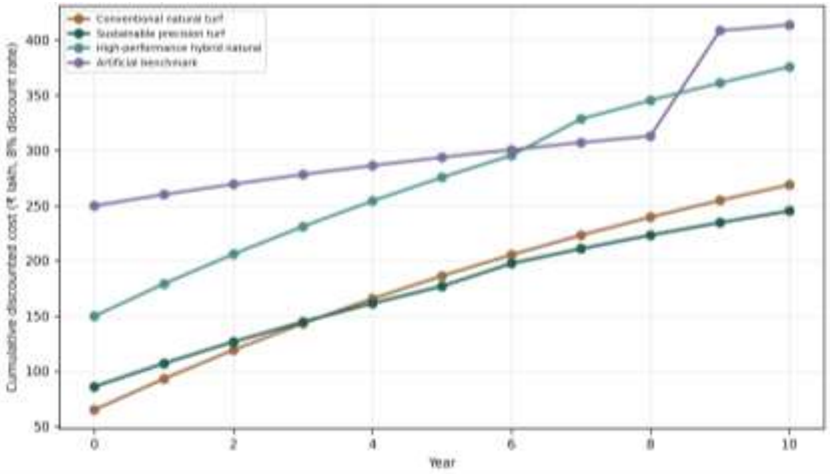


**Figure 4. Ten-year discounted lifecycle cost comparison**

*Source: At an 8% discount rate, the author's model includes the scheduled midlife repair or replacement. The use of artificial turf is included in the model as a procurement benchmark.*

**Interpretation:** While the upfront investment for precision irrigation and upgraded rootzone construction is greater, the long-term savings make it the more cost-effective option. The artificial benchmark starts with the highest upfront investment and incurs the cost of the largest replacement in year nine. Hybrid natural turf is also the most expensive of the natural options, but the investment may be warranted in situations where there are documented increases in playable hours, broadcast quality, or event revenue. Therefore, lifecycle management decisions should be made considering the cost per safe playable hour, as opposed to the overall cost.


**Figure 5. Sensitivity of sustainable precision-turf annual cost**

*Source: Author's one-way sensitivity analysis around the 2025-price base scenario.*

**Interpretation:** Within the parameters assessed, labour inflation poses the most significant risk, followed by inflation in the cost of water and energy. The most significant, controllable cost savings potential are found in substitution of irrigation water with recycled water and the use of irrigation sensors. The outcome of this assessment also reinforces the prioritisation of investment in improvement of the water infrastructure and an increase in the capability of the personnel, rather than a reduction in the frequency of maintenance.

### 8.1 Economic decision rules

A venue should choose the system with the lowest cost that satisfies the required playable hours and quality threshold. For a low use school field, seeded bermudagrass might be the best option. A professional stadium might require hybrid

reinforcement, undersoil ventilation, or grow lights. There is unnecessary cost placing stadium specifications on a community ground, and there is a high risk of failure placing community specifications on an elite venue.
The business case for sustainability includes avoidance of closures, lower renovation frequency, reduction in tanker water, fertilizer, and emergency treatments, and increased asset life. These costs are avoided, and they are not accounted for in an annual budget because they are irregular costs. These costs become visible in a five or ten year asset plan.

## 9. Business Opportunities in India

### 9.1 Certified planting material and regional nurseries

The biggest foundational gap is reliable planting material. Having certified sod or seedlings or seeds with traceable cultivar identity would reduce failure of establishment and provide guarantees of performance. Transport damage would be minimal with regional nurseries near the major sports clusters, and rapid replacement after events would be supported. The framework of a commercial model involves multiplication licenses, contract growing, and installation.
A valid certification system should check the genetic identity, purity, pest status, cutting condition and rooting strength. This would allow differentiation from generic landscaping turf and would justify a premium for sports-grade material.

### 9.2 Design-build-maintain and renovation services

Integrated contractors can handle every phase of a project from grading and drainage to rootzone construction and irrigation as well as project establishment and maintenance for several years. This approach addresses the issue of the discontinuity of the civil works and plant establishment. There are also renovation services like fraze mowing, aeration, topdressing, and replacement of sod, which also help to maintain a revenue stream from clients.
Contracts can be adjusted to award the contractor for specific field functions, such as cover percentages, infiltration, hardness, and evenness, as well as for the response time of repairs.

### 9.3 Precision technology, testing and data services

Precision irrigation technology can be developed to suit many different price points, from low-cost soil moisture probes and flow alerts, to integrated weather stations, drone mapping, digital maintenance logs, and valve level control. Within the Indian market, modular systems that can be serviced locally and operate under intermittent connectivity are likely to be the most desirable.
Service development options are also presented by independent testing and certification. Field owners are looking for pre-opening acceptance tests, injury risk indicators, seasonal audits, and evidence for procurement disputes. Mobile testing units and regional reference ranges can be developed by private labs and universities. According to Parra et al. (2024), drone technology within turf is still an emerging area, therefore, the development of many applied services is still possible.

### 9.4 Treated-water integration, training and shared machinery

Phased and modular engineered systems can be used jointly by wastewater services, stadium managers and irrigation companies to provide treatment, supply and storage of treated water. Further services include treatment to specific quality requirements, mixing, filtration, salinity control and preparation of supporting documents. This opportunity is sustainable but requires significant technical and institutional efforts.
Proper training is necessary because sophisticated systems can be rendered useless due to lack of knowledgeable operators. Short workshops can be held to instruct on the identification of the mentioned species, irrigation audits, setup of mowers, scouting diseases, testing surfaces, and even on budgeting. Also, to support municipalities and schools who cannot afford a complete system, aeration devices, topdressing machines, laser graders and special mowers can be provided on a lease basis or through shared service fleets.

**Table 6. Business opportunity assessment**

| Opportunity | Attractiveness | Entry barrier | Sustainability value | Likely providers |
|---|---|---|---|---|
| Certified sod and planting material | 4.5 | 3.0 | 4.3 | Nurseries, breeders, sports contractors |
| Design-build drainage/rootzones | 4.8 | 4.2 | 4.8 | Civil-turf joint ventures |
| Precision irrigation and sensors | 4.4 | 3.4 | 4.9 | Irrigation firms, ag-tech startups |
| Maintenance-as-a-service | 4.7 | 2.4 | 4.2 | Turf contractors, facility firms |
| Field testing and certification | 3.6 | 4.0 | 4.8 | Universities, labs, consultants |
| Treated-water integration | 4.1 | 4.3 | 5.0 | Utilities, EPC firms, water-tech providers |
| Training and operator certification | 4.0 | 2.1 | 4.4 | Institutes, associations, OEMs |
| Equipment leasing and shared services | 4.2 | 3.2 | 3.8 | Machinery dealers, service cooperatives |

**Interpretation:** Highly attractive to large markets with continuous demand are design-build rootzones and maintenance-as-a-service. Precision irrigation is highly sustainable with moderate entry barriers. There are high institutional barriers for testing and integration of treated water, however, they can be positioned as defensible specialist businesses with little competition.

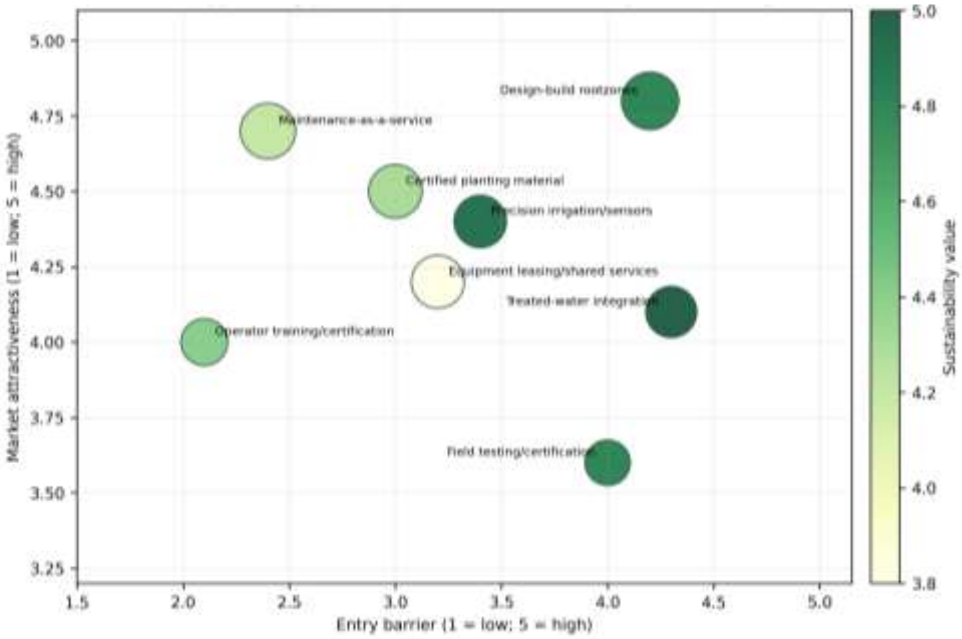


**Figure 6. Business opportunity portfolio for sustainable sports turf**

*Source: The size of each bubble represents the author's anticipated revenue from each deal, not market value. Each bubble's score results from the author's judgement on the strategic importance of each engagement.*

**Interpretation:** In the top left corner of the portfolio, you see enticing opportunities that have low entry barriers. These include maintenance services and training. They are followed by higher-value segments such as rootzone construction and treated-water integration which are technically more challenging located in the top right of the portfolio. These are followed by a market-entry strategy that first incorporates maintenance or nursery services and subsequently adds testing, technology, or design.

## 10. Procurement, Governance and Risk Management

Performance-based procurement requires a paradigm shift on the part of the purchaser. Tender documents should include the intended field use, the desired date the field becomes operational, the anticipated year-round schedule of use, the source of water, the light environment, the drainage, Rootzone and turfgrass specifications, the preferred establishment methodology, maintenance responsibilities, and criteria for acceptance testing. Descriptive references such as “Bermuda grass lawn” are insufficient for the development of professional sports assets.

The establishment biology must be factored into the risk allocation. The completion of the construction milestone and the playable opening are not the same. Sufficient time for biological establishment must be considered, and the owner must have the legal right to restrict access for certain uses (i.e., traffic) prior to the opening. The contract should also include the maintenance manual, spare-parts plan, and the curriculum for operator training.

In the context of environmental governance, a water budget, records of irrigation flows, a nutrient management plan, a pesticide inventory, wastewater analysis, and a renovation waste management plan also must be considered. These records will facilitate ESG reporting and will safeguard the venue during periods of drought and other externally driven unfavorable conditions.

**Table 7. Principal risks and controls**

| Risk | Likely consequence | Control |
|---|---|---|
| Wrong species or cultivar | Poor recovery, dormancy, excessive inputs | Site diagnosis, trial plots, certified material, cultivar specification |
| Inadequate drainage | Closures, disease, compaction and root loss | Survey, grading, tested drainage capacity, outlet maintenance |
| Uniform irrigation on variable soil | Waste, dry spots and salinity accumulation | Catch-can audit, moisture mapping, zoning, flow monitoring |
| Overuse without recovery | Loss of cover and unsafe surface | Playable-hour budget, traffic rotation, protected recovery days |
| Low-skilled maintenance | Machinery damage, overwatering, weak diagnostics | Operator certification, SOPs, supervision and performance KPIs |

| | | |
|---|---|---|
| Lowest-capex procurement | High lifecycle cost and repeated renovation | Whole-life cost, performance warranty and maintenance plan |
| Unverified recycled or treated inputs | Salinity, contamination or physical incompatibility | Laboratory testing, blending and documented quality limits |
| Technology without service support | Sensor failure and abandoned systems | Open standards, local support, manual fallback and data ownership clauses |

**Interpretation:** Most failures of an endeavor are due to system failures rather than failures of the constituents that the system is built of. The same species of grass can grow in a variety of ways under varied drainage conditions and under different controlled and uncontrolled levels of traffic. As such, risk control is the combination of the right biological selection and the right construction, operating, and contractual disciplines.

## 11. DISCUSSION

The data support a regional selection approach rather than a single selection approach. For most heavily trafficked areas in the U.S. where warm-season turf is appropriate, Bermudagrass is the dominant choice. For most situations, the decision between elite hybrids, and seed types, is typically determined by available budget and desired quality. In low-input systems, where recovery from wear is less of a concern, Zoysiagrass is a viable choice. In saline affected areas, Seashore Paspalum is a viable choice. For cooler temperatures, and the establishment of a playable, low-maintenance turf, the use of Rylgrass is appropriate.

This economic model directly contravenes two prevailing ideas. The first is that higher annual expenses equate to greater sustainability. In this model, the sustainable option is more costly in the short term, but less costly over the long term. The second is that due to the elimination of mowing and irrigation, sustainability is assumed cheaper long-term, because of the turf's lower operating cost. Recent long-term studies have shown that the outcomes vary greatly because of the local context and the way the turf is maintained and the intensity of its use (Russo et al., 2022; Zeilerbauer et al., 2024; Cumberbatch et al., 2025). Natural turf is sustainably economically attractive when it is professionally maintained and its use is intense and recovery is appropriate.

In the context of turf, hybrid reinforcement is best understood as a capacity product. In turf, stitched reinforcement did not improve every traffic outcome, and therefore, hybrid technology cannot be viewed as a replacement for species and vegetative management. Its value should be measured through the additional playable hours and stability under event load and catastrophic failure.

The paper also identifies a gap in research. India requires tests for replicated cultivars in a range of representative climates, use of treated water, creation of local cost databases, development of surface-safety criteria and lifecycle assessments in cricket and football, and use of Indian data and resources. Until these datasets are created, procurement will be based on imported data and supplier experience.

A national sports/turf network could connect the ICAR, universities of horticulture, sports authorities, stadiums, and the private sector. Development of a common protocol would facilitate multi-location trials for bermudagrass, zoysiagrass, paspalum, and seasonal overseeding. Findings could be published as regional preferred lists and used as specifications for tenders.

## 12. Practical Decision Framework

Decision-makers should follow a specified order. To begin, the terminology that should be defined as part of the framework includes: sport, event hours, training, and recovery. The next step is to define the variables comprising the climate and the quality of the soil and water. The following step will address the selection of species and cultivar that will pose the lowest biological risk. After that, the appropriate root zone and irrigation will be determined based on the requirement of the desired goal. Lastly, the implementation and the management of the service will be based on the data provided.

For the hot-dry climate of an urban football field, the likely solution includes the use of an irrigation system coupled with soil moisture sensors, improved native soil, and the establishment of seeded bermudagrass. For an elite coastal stadium, using marginal water, the likely solution will be the installation and use of highly drained root zones with salinity monitoring coupled with the establishment of salt tolerant bermudagrass and seashore paspalum. For a professional field that has high use and a high revenue field, the establishment of hybrid bermudagrass is likely warranted. For a coastal university field, the establishment of zoysiagrass may result in the lowest input burden.

## 13. Recommendations

1. Implement regional species zoning and eliminate national grass type restrictions.
2. Establish identity and certification of planting material for all valuable fields.
3. Use the quality of light and water combined with the intensity of field use as primary inputs for design.
4. Define uniformity of drainage and irrigation and performance of root zone before aesthetics.
5. Create water budgets and use soil moisture control, rain shut off, leak detection, and treated water substitution in that order.
6. Use cover, infiltration, hardness, traction, closure hours, and other measurable parameters as maintenance contract performance indicators.
7. Consider the entire project lifecycle, including renovation, replacement, and downtime, when budgeting.
8. Create regional, public, and educational field equipment-sharing and operator-certification programs.

9. Create Indian multi-location cultivar testing and a national sports turf performance database.
10. Create viable business models that integrate certified turf, design, build, maintenance, and data services.

## 14. CONCLUSION

Creating sustainable sports turf in India is a difficult balancing act. Climate and stress impact species and turf construction, respectively. The intended use will dictate construction. The maintenance system will need to adapt to the owner's capabilities over time. Hybrid and seeded Bermudagrasses address the needs of the vast majority of Indian fields. For moderate recovery situations, Zoysiagrass is lower maintenance and tolerates some shade. For coastal and marginal water fields, Seashore Paspalum is the best option and Ryegrass should be reserved for temporary or cool weather use.
From the economic perspective, precision agriculture for natural turf fields becomes a less expensive over ten years, despite higher initial costs. It saves costs in the long run due to better management of water use and field maintenance. It also creates a business ecosystem for planting materials, construction, maintenance, irrigation services, and the repair and training for the use of agricultural technology.
The next stage for India is evidence infrastructure: Based on local cultivar trials, standard surface tests, auditable cost records and performance-based procurement, natural turfgrass can provide safer play, lower lifecycle costs, water stewardship and more green services as aligned with India’s growing sports needs, particularly with respect to sustainable play surfaces.

### Data Transparency and Limitations

Official numbers regarding India's climate and sports budget are cited from original government sources. Species scores are evidence-normalized synthesis values, and as such, should not be taken as direct means of cultivar trials from India. Cost figures represent an engineering scenario for planning and comparison purposes and do not reflect a national market survey or supplier quotation. Owners must replace assumptions with site-specific data, and must gather information regarding water tariffs, cost of labor, soil testing, irrigation, construction volumes, and the expected number of playable hours before making an investment.
This paper has been structured to serve as a decision-making framework for the development of a journal paper. Submission to a Q1 journal would be further substantiated by the completion of multi-site field trials, surveys of stakeholders, or Indian case studies with an audit.

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