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Accounting of good agricultural practices in north-western hill agri-food systems

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Accounting of Good Agricultural Practices (GAPs) in hill agri-food systems means tracking, quantifying and reporting the financial costs, environmental impacts and compliance premiums of sustainable mountain farming. The GAPs address the main weaknesses of hill agriculture such as water erosion, moisture stress, declining soil fertility and low diversification; and support climate resilience by improving infiltration, reducing runoff and stabilising production under aberrant conditions. Monetary accounting covers two linked benefits i.e. direct farm gains, and the additional value of the ecosystem services that GAPs protect or enhance. Thus, GAPs, raise private income and can also justify payments for ecosystem services, because society benefits from cleaner water, healthier soils, carbon storage and biodiversity.

Keywords: Conservation agriculture, North-western Himalaya, Payments for ecosystem services

GOOD Agricultural Practices (GAPs) in the north-western hill agri-food system are a bundle of site-specific measures that protect fragile slopes, conserve soil and water, diversify farm income and improve food safety and resilience. In this region, GAP is the alignment of farm management with steep terrain, rainfall variability and smallholder constraints. Steep slopes, high transport costs, climate vulnerability and fragmented holdings all alter the cost–benefit structure of GAP certification.

Core GAP elements in hill agriculture

- Contour-based land use, terrace maintenance, and erosion control to reduce runoff and soil loss on slopes.
- Mulching, residue retention, cover crops, and minimum soil disturbance to conserve moisture and protect soil biology.
- Integrated nutrient management using compost, manure, green manures, and legumes to maintain fertility with lower dependence on synthetic inputs.
- Diversified cropping through intercropping, crop rotation, mixed cropping, and agroforestry to stabilise yields and spread risk.
- Farm water harvesting and micro-catchments to improve rainfall use efficiency in rainfed hill systems.
- Better livestock integration, fodder trees, and grass-legume mixtures on terrace risers or marginal land to reduce pressure on forests and recycle nutrients.
- Seed conservation, local germplasm use, and farmer knowledge sharing to strengthen resilience and reduce external dependence.

Importance of GAPs accounting in hill agriculture

GAPs address the main weaknesses of hill agriculture (water erosion, moisture stress, declining fertility and low diversification) and support climate resilience by improving infiltration, reducing runoff and stabilising production under erratic rainfall. In food-system terms they move households from low-output monocropping towards more secure, diversified and nutritious production.

For the north-western Himalaya, the most defensible GAP package combines contour farming, terrace improvement, water harvesting, organic matter management and crop–tree–livestock integration. Monetary accounting then covers two linked benefits i.e. direct farm gains, and the additional value of ecosystem services the package protects or enhances. Thus, GAPs raise private income and can also justify Payments for Ecosystem Services (PES), since society gains cleaner water, healthier soils, carbon storage and biodiversity.

Table 1. Practical accounting framework for north-western hills

GAP domain	TEEB Capital	What to record	Typical indicator
Soil conservation	Natural	Terraces, contours, bunds, mulching, residue cover	% area under conservation measures
Water management	Natural	Harvesting structures, farm ponds, irrigation efficiency	Water storage capacity or irrigated area
Nutrient management	Produced	Compost, FYM, green manures, legume use	Share of nutrient input from organic sources
Crop diversification	Produced	Intercropping, rotation, mixed cropping, horticulture	Crop diversity index or number of enterprises
Agroforestry/ livestock	Produced	Trees, fodder strips, silvi-pasture, livestock integration	Tree density or fodder area
Knowledge and adoption	Social	Training, farmer field schools, seed sharing	Number of farmers trained/ adopting
Manpower management	Human	Number of manpower engaged	Mandays/ha/ year

Monetary benefits of GAP

- Higher and more stable yields from better soil moisture, fertility, and reduced erosion can be translated into extra net farm income.
- Lower input costs arise from composting, nutrient recycling, integrated pest management, and reduced fertiliser loss.
- Reduced risk and crop failure costs matter especially in hill systems, where slope management and water conservation stabilise production.
- Diversification through agroforestry, intercropping, and livestock integration adds multiple income streams and spreads income risk.

Ecosystem service value

The GAPs also produce public benefits not captured in market prices like carbon sequestration, improved infiltration and water quality, soil retention and biodiversity conservation. Economic valuation shows that such non-tradable ecosystem services can form a substantial share of the total benefits from sustainable farming interventions.

Payments for Ecosystem Services

The PES pays farmers for measurable stewardship outcomes or approved practices that maintain ecosystem services. Payment should be comparable to the farmer's opportunity cost, so that adoption is attractive. In agriculture this can mean payments for terrace maintenance, mulching, cover crops, reduced tillage, agroforestry, riparian buffers or soil and water conservation structures. Watershed programmes show that improved water quality and quantity can outweigh the cost of reduced agricultural output, giving a benefit-cost ratio above one.

Table 2. A practical accounting format for calculating Payments for Ecosystem

Item	What to value	Monetary expression
Direct farm benefit	Yield gain, cost saving, reduced losses	Extra net income per ha
Risk reduction	Lower crop failure, greater stability	Expected avoided loss per ha
Ecosystem services	Water regulation, soil retention, carbon, biodiversity	PES or shadow price per ha
Total benefit	Direct + indirect + public value	Net social benefit per ha

GAP in hill agriculture should be treated as a dual-value investment. It improves farmer profitability while generating public environmental goods that can be rewarded through PES.

Conservation agriculture for accounting GAPs in hill agriculture

Conservation Agriculture (CA) in India's hill agri-food systems is an ecosystem-based approach designed to reverse soil degradation, optimise water-use efficiency and reduce cultivation costs. Unlike intensive tillage, which leaves mountain slopes exposed to monsoon downpours, CA works through mechanical stability and biological regeneration. It rests on three inseparable principles:

***Minimum soil disturbance*:** Conventional ploughing on slopes is eliminated, particularly during the rains. Farmers plant directly through the residue using local desi ploughs with a *pora* attachment or lightweight, mountain-adapted zero-till seed drills, maintaining the structural integrity of the soil matrix and preventing the loosening of earth that triggers slope failure.

***Permanent soil organic cover*:** At least 30% crop residue cover is maintained using maize stalks, wheat straw or weed mulches, or dedicated cover crops. This layer absorbs the kinetic energy of monsoon raindrops, reducing splash erosion, and cuts surface evaporation through the dry summer.

***Species diversification*:** Mountain monocultures give way to deep-rooting legumes such as horse gram, cowpea and lentil mixed with cereals including finger millet, maize and paddy. Varied root architectures bind



Direct planting through residue using a local desi plough with *pora* attachment



In-situ live weed mulching between maize rows at 30–35 days after sowing



Legume intercropping between maize rows for diversification, splash erosion control and natural weed control

different soil layers, while legumes fix atmospheric nitrogen and reduce the need for imported synthetic inputs.

Ecosystem service accounting (ESA) for conservation agriculture practices in hill agriculture

When calculating the environmental balance sheet for CA under the UN SEEA framework, the practices generate distinct economic values that can be commodified into green credits:

***Carbon sequestration*:** By leaving soil undisturbed and retaining residues, CA acts as an effective carbon sink. Soil organic carbon accumulation can be quantified in tonnes of CO_2 equivalent per hectare, opening access for FPOs to voluntary carbon credit markets.

***Energy and fuel savings*:** Eliminating tillage cuts diesel consumption or human energy expenditure by 60–80%, an immediate operational cost reduction and a lower farm-level carbon footprint.

***Water allocation*:** Increased infiltration under CA acts as *in-situ* groundwater banking, reducing dependence on expensive downstream lift irrigation and lowering public utility costs.

Evaluating conservation agriculture for a maize–wheat crop rotation

The maize–wheat rotation dominates food security across the Indian hills. Under conventional farming, maize stalks are cleared or burnt and fields intensively ploughed before wheat sowing, accelerating topsoil erosion just before winter. Transitioning this rotation to CA changes field operations, resource timelines and financial line items.

***Agronomic protocol for maize–wheat CA in hill systems*:** Implementing CA in a maize–wheat system requires precise timing and specialised tool handling to manage the heavy biomass of both crops.

- **Maize phase (*kharif*):** Maize is sown directly into the previous winter's wheat residue using a desi plough with *pora* attachment or a lightweight hill-adapted zero-till drill. The main challenge is managing monsoon weed growth without tillage, which requires pre-emergence eco-herbicides or dense leguminous cover crops such as cowpea or black gram between maize rows.
- **Wheat phase (*rabi*):** Maize is harvested at the end of the monsoon, leaving stalks cut at 15–20 cm intact. Wheat is drilled directly into this standing residue, which insulates the soil, traps residual moisture and protects seedlings from severe mountain frost.
- **The residue dilemma:** Maize stalks are valued as winter fodder in hill communities. Partial residue retention resolves the conflict i.e. the leafy tops are harvested for fodder while the bottom 30–40% of woody stalks stays on the field to meet minimum ground cover.

***Financial ledger impact*:** Transitioning to CA changes a farm's cash flow by shifting expenses from heavy tillage labour to specialised seeding equipment and early-stage weed management.

***Resource efficiency trade-offs*:** The main financial return from this rotation comes from saving water, fuel and labour. Conventional tillage loses substantial soil moisture to evaporation in the hot turnaround between

Table 3. Financial ledger: Conventional versus conservation agriculture in a maize–wheat rotation (₹/ha/year)

Cost/Revenue center	Conventional maize–wheat (₹/ha/yr)	CA maize–wheat (₹/ha/yr)	Accounting and operational treatment
Land preparation	14,000	2,500	Major saving: 3–4 ploughing/planking passes eliminated
Sowing and seeding	4,500	6,000	Initial investment: zero-till machinery hire or jab planters
Weed management	3,000	5,500	Higher in years 1–2 until cover crops establish
Irrigation / Water	6,000	3,500	Residue mulching cuts wheat irrigations by 30%
Fertilizer input	11,000	8,500	Better moisture retention raises fertiliser use efficiency
Average net yield value	62,000	66,500	Yields stabilise and improve by year 3



In-situ live green manuring of *Sesbania* between maize rows at 30–35 days after sowing

monsoon harvest and winter sowing; this to germinate reliably even when winter rains are delayed.

***Ecosystem service valuation for maize–wheat CA*:** For Farmer Producer Organizations (FPOs) or regional carbon projects, this system generates clear environmental values that can be written into green asset registries:

- **Soil organic carbon accumulation:** Research across Indian hill ecosystems shows zero-till maize–wheat systems raising topsoil organic carbon by 0.4–0.6% annually, convertible to carbon credits at 1.2–1.8 t CO_2-eq sequestered per hectare per year.
- **Nitrogen credit equivalent:** Retaining leguminous cover crops or residues prevents leaching of residual nitrogen into mountain streams, saving an estimated 25–30 kg of nitrogen per hectare annually, valued at local urea rates.
- **Extended growing window:** Avoiding the 10–14 days traditionally spent ploughing dry fields lets farmers sow winter wheat earlier, protecting the crop from terminal heat stress during grain filling and reducing the financial risk of climate-induced failure.

Implications and policy mainstreaming

These findings offer entry points for mainstreaming the TEEBAgriFood framework into agricultural and natural-resource policy. Ecosystem service assessment and valuation can be built into initiatives on sustainable agriculture, watershed and spring-shed management, natural farming, horticulture, agroforestry and climate-resilient agriculture, including NMSA, PMKSY, MIDH, the Soil Health Card Scheme and watershed development. Indicators of soil retention, water regulation, carbon balance, biodiversity and livelihood benefits, incorporated into planning, monitoring and evaluation, would make the wider benefits of GAPs visible and support PES, targeted incentives and performance-based investment.

SUMMARY

Good Agricultural Practices and conservation agriculture generate services rarely captured in conventional farm accounting like soil retention, water regulation, carbon sequestration, nutrient cycling, biodiversity conservation and reduced climate-related production risk. In the north-western hills, contour farming, terrace improvement, water harvesting, residue retention, organic matter management and crop–tree–livestock integration raise private returns while delivering these public benefits. The TEEBAgriFood framework offers a systematic pathway for recognising them, linking changes in natural, human, social and produced capital with ecosystem service flows and wider outcomes. Making these hidden values visible through biophysical and economic assessment improves farm and policy decisions, and integrating ecosystem service accounting into hill agricultural programmes can support PES, natural-capital stewardship and more resilient, sustainable and inclusive agri-food systems.

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National Pest Surveillance System

Launched on 15th August 2024 to enhance the surveillance and management of pest diseases across the country. The system utilises latest digital technologies such as Artificial Intelligence and Machine Learning (AI and ML) to provide quick and instant solution regarding pest attacks, crop diseases, crop damages, etc. by issuing real time crop protection advisory to the farmers. It includes a user-friendly mobile app and a portal for identification of pests and disease mitigation through integrated pest management.

NPSS