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True-value accounting of human capital in sustainable agriculture: Rethinking value of agricultural production

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Traditional agricultural metrics focus strictly on yield and profit, masking the heavy human toll of farming. This paper introduces a specialised True Value Accounting (TVA) framework to track the true state of human capital in agriculture. Beyond simple labour output, this model accounts for farmer health, nutrition, time, workload, and skills. Crucially, it treats malnutrition, physical illness, and severe drudgery as direct capital depreciation rather than hidden externalities. By shifting from narrow crop metrics to human balance sheets, this framework provides a practical tool to maximise both farm income and family well-being.

Keywords: Agricultural productivity, Human health, TEEB AgriFood

AGRICULTURAL performance is conventionally assessed through yield, gross returns, net returns, benefit-cost ratio, labour productivity and resource-use efficiency. These measures are essential for farm-level decision-making, but they do not fully represent the value created or depleted through agricultural production. A sustainable farming system creates value not only through financial returns but also by conserving soil and water resources, reducing post-harvest losses, recognising family labour, and improving the efficiency, safety and well-being of women and men engaged across the farm and food value chain.

The challenge, therefore, is not simply to produce more, but to determine how much value agriculture creates, which forms of capital generate that value, who contributes to it, who benefits from it and what is depleted in the process. This provides the rationale for True Value Accounting (TVA) in sustainable agriculture. TVA expands conventional farm accounting by recognising changes in natural, produced, human and social capital and connecting them with production, food, nutrition, livelihoods and ecosystem outcomes. The approach is particularly relevant to diversified, smallholder including tribal farming systems where market transactions represent only a fraction of total household agricultural value.

From farm income to a four-capital balance sheet: Linking with TEEB AgriFood

A farming household operates as a portfolio of four interdependent capitals aligned with the TEEB AgriFood framework to drive productivity, resilience, and value creation:

***Natural capital*:** Environmental foundations including soil, water, biodiversity, biomass, and ecosystem functions.

***Produced capital*:** Physical assets including farm machinery, irrigation structures, storage, and processing equipment.

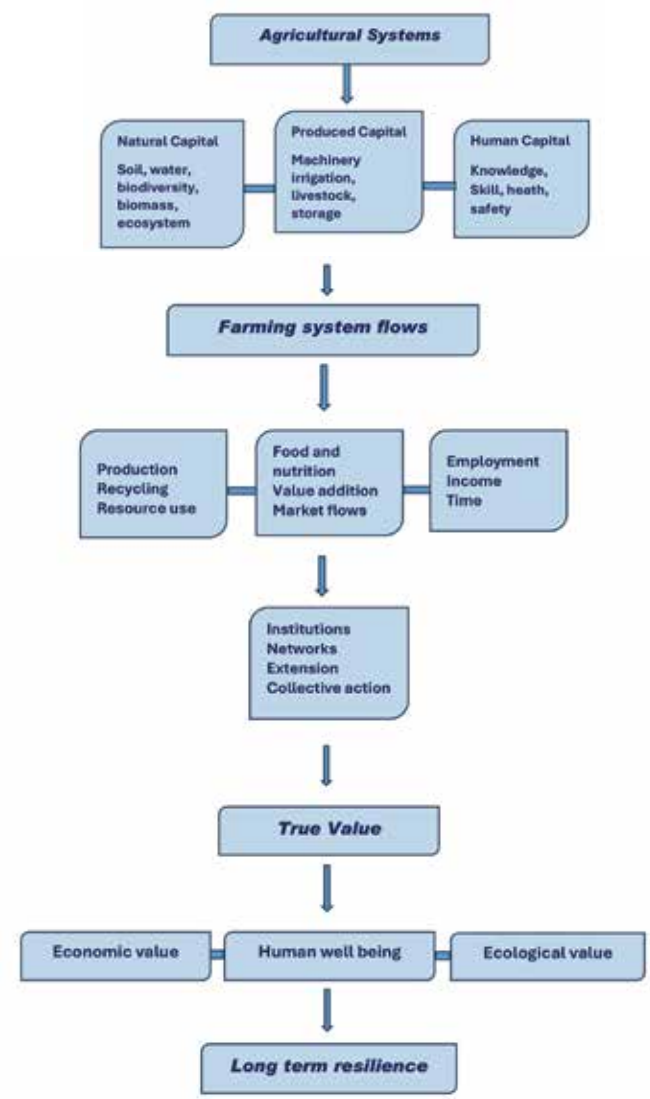
***Human capital*:** Worker capacities including health, physical endurance, occupational safety, skills, and decision-making agency.

***Social capital*:** Institutional networks including farmer organisations, collective action, trust, and market linkages.

These capitals interact continuously. Natural resources provide the foundation for production; produced assets transform resources into outputs; human capability operates and manages the production system; and social institutions determine access to knowledge, technology, markets and collective resources.

Human capital: The missing asset in farm accounting

Human capital remains poorly represented in agricultural economics, as conventional farm budgeting treats family labour as a mere production input by tracking raw labour-days or imputed wages. In reality, human beings bring knowledge, physical capacity, and entrepreneurial skills into farming, meaning human



Conceptual relationship between capital stocks, farming-system flows, outcomes and true agricultural value

capital has both a productive and a depletion dimension. This relationship can be expressed through a conceptual framework:

Net human capital value = Productive capability created − Capability consumed or degraded

While training, improved nutrition, and occupational safety enhance capability, factors like excessive workloads, musculoskeletal injuries, and chronic fatigue accelerate capital depreciation. Consequently, farming systems requiring identical quantities of labour-days cannot be considered equivalent if one rapidly consumes the physical well-being of the workforce. Among the four capitals, human capital remains one of the least adequately represented in agricultural economics.

From labour use to human capital productivity

Consider two farming systems that generate similar farm income. The first requires prolonged manual operations, heavy load carrying and repetitive work. The second uses appropriate mechanisation and ergonomic tools, reducing physical workload and time required. The second system potentially preserves human capability while freeing time for childcare, education, entrepreneurship, value addition, community participation or rest. Therefore, time saved is not merely a reduction in labour cost; it can be an addition to human capital.

Nutrition as the foundation of agricultural human capital

Nutrition anchors agricultural human capital, directly dictating the physical and cognitive capacity available for production. By measuring raw labour-days while ignoring underlying nutritional deficits, conventional accounting overestimates sustainable workforce availability, especially for women. Survey data from 100 tribal households in Ramnagar, Nainital confirmed that female farmers bear a disproportionately higher nutritional burden, imposing a severe, hidden bodily cost. Within a human value accounting framework, indicators like undernutrition, stunting, and wasting are treated as asset depreciation and monetised by compounding immediate productivity losses, medical expenditures, and children's future lifetime earnings drops. This exposes a critical sustainability paradox. Farming households frequently generate short-term agricultural income by liquidating their future productive capacity through human-capital depletion. Ultimately, labour productivity is inseparable from nutritional security, meaning true agricultural value must reflect whether a system preserves or destroys the human assets required for future production.

The most important human capital finding is arguably the nutritional condition of children. Among children aged 0–5 years, 85.71% of boys were stunted, while 80% of girls were wasted and 80% were undernourished according to the reported indicators. These results have a direct implication for TVA. Current agricultural income fails as a complete measure of household welfare if the underlying production system fails to sustain adequate nutrition for the next generation. A farming system that yields financial profit while leaving children chronically undernourished is generating immediate cash at the direct expense of future human capital. This introduces a critical intergenerational dimension into agricultural economics i.e. the true value of production today must be evaluated by whether it strengthens or liquidates the productive capabilities of tomorrow's workforce and entrepreneurs.

Food-value chains: Human capital perspective

Farm-level production does not represent the full value created by farmers and workers. When produce is lost after harvesting, the labour, time, skills, and physical effort invested in producing that food are also partly lost. From a TVA perspective, post-harvest loss can therefore be treated as a loss of human capital, because human effort has been expended without generating its intended food and economic value.

Human capital loss = Labour time invested in lost produce × Economic value of labour

Reducing post-harvest losses through better harvesting, storage, grading, transport, processing, and marketing can therefore improve the return generated

Table 1. Difference between conventional and true value accounting on human capital

Conventional accounting	Human capital accounting
Labour-days	Labour-days and time burden
Wage cost	Opportunity cost of time
Labour productivity	Productivity adjusted for workload
Machinery cost	Labour-saving and ergonomic benefit
Farm income	Income, time and health benefits
Technology adoption	Technology access, capability and agency
Family labour	Productive and unpaid contributions
Physical workload largely externalized	Drudgery, fatigue and ergonomic burden accounted
Health treated largely as a private issue	Work-related health burden recognized as a production cost
Output maximisation	Sustainable output with preservation of human capability

from existing human effort. The value can be assessed through the labour embodied in produce recovered, additional income generated, and employment created through value addition.

Net human capital value = Value of labour embodied in produce recovered + Additional income/ employment benefits − Value-chain improvement costs

Thus, reducing food loss is not only about saving food; it is about preserving the value of human labour, skills, time, and effort already invested in production. TVA consequently recognises post-harvest loss as a hidden cost to human capital and loss reduction as an investment in converting human effort into realised economic and social value.

Making women's contribution visible though ergonomics in human value accounting

Conventional accounts mask women's extensive unpaid roles in crop establishment, weeding, harvesting, and livestock management, severely undervaluing their agricultural contributions. Ergonomic data from the standard nordic questionnaire reveals that this hidden burden causes highly unequal physical capital depletion, with female farmers suffering disproportionate lower-back, shoulder, and wrist pain due to heavy, poorly designed traditional tools. Integrating this bodily wear and tear into human value accounting redefines subjective musculoskeletal discomfort as direct asset depreciation, transforming descriptive gender analysis into a measurable indicator of structural inequality and labour exploitation.

To incorporate this dimension into human value accounting, a Physical Human Capital Depletion Index (PHCDI) can be estimated as:

$$PHCDI = \frac{\sum_{i=1}^{9} Pi}{9}$$

Where P_i, Percentage of workers reporting discomfort in each body region. The monetary value of this physical burden can then be estimated by linking discomfort to lost work capacity:

$$\text{Monetary PHC Loss} = N \times D \times W \times R$$

Where N: Number of affected workers, D: Number of workdays lost or affected, W: Daily value of labour, R: Proportion of productivity loss. This formula brings hidden ergonomic costs into economic ledgers, proving that gender inequality extends far beyond wage gaps to the unequal physical depletion of human capital.

Physiological workload as a measurable component of human capital depletion

Physiological workload provides an important objective complement to perceived musculoskeletal discomfort in assessing the depletion of physical human capital. Evidence from studies conducted on sugarcane operations demonstrates that activities such as de-topping, de-trashing, and head-loading can impose substantial physiological and postural demands, while manual paddy operations show that even activities classified as light or very light may involve considerable postural discomfort. This distinction highlights that energy expenditure alone cannot capture the full physical cost of agricultural work. Therefore, standard labour-days are not economically equivalent. A drudgery-adjusted human capital account balances this by tracking:

- ***Physiological strain*:** Heart-rate response and energy expenditure.
- ***Ergonomic stress*:** Awkward postures, repetitive movements, and load carrying.
- ***Operational reality*:** Task duration, fatigue, health risks, and access to labour-saving tools.

To quantify the hidden biological costs of physical human capital (PHC) depletion, empirical physiological and ergonomic data are converted into monetary losses using a structural valuation equation.

Monetary PHC Depletion = Productivity Loss + Workdays Lost + Health Costs

- ***Productivity loss*:** Evaluated through reduced daily work capacity or lower field output.
- ***Workdays lost*:** Measured through absenteeism and the inability to perform scheduled agricultural tasks.
- ***Health costs*:** Calculated from direct medical treatment and related care expenditures.

This approach makes the hidden physical cost of agricultural production visible within human value accounting and allows different forms of agricultural work to be evaluated according to the human capital they consume.

Technology as an investment in human capital

Another study conducted on comparing of traditional and improved agricultural tools demonstrates that technology can create value not only through higher production efficiency but also by reducing the physical burden on workers. Evidence from improved sickles and brush cutters shows that better technology can reduce physiological workload, labour time, and drudgery while improving working efficiency. From a



Paddy harvesting through traditional sickle



Paddy harvesting through improved sickle



Paddy harvesting through brush cutter

Table 2. Perceived musculoskeletal discomfort across gender

Agricultural activity/tool	Body part	Male (%)	Female (%)
Traditional spade 	Lower back	32.5	70.0
	Shoulder	12.5	60.0
	Wrist	15.0	50.0
Khurpi 	Wrist	40.0	48.0
Traditional sickle 	Wrist	30.0	32.35
Sugarcane harvesting knife (*Balkati*) 	Shoulder	50.0	88.8
	Lower back	32.5	44.4

human value accounting perspective, these reductions represent a potential investment in preserving physical human capital.

Agricultural technologies should be evaluated by both their productive output and their human-capital preservation effects, rather than being viewed as mere labour substitutes. Beyond reducing labour hours, modern tools lower physiological strain, reduce musculoskeletal injuries, and sustain long-term work capacity. This economic asset preservation can be quantified through a structural balance sheet:

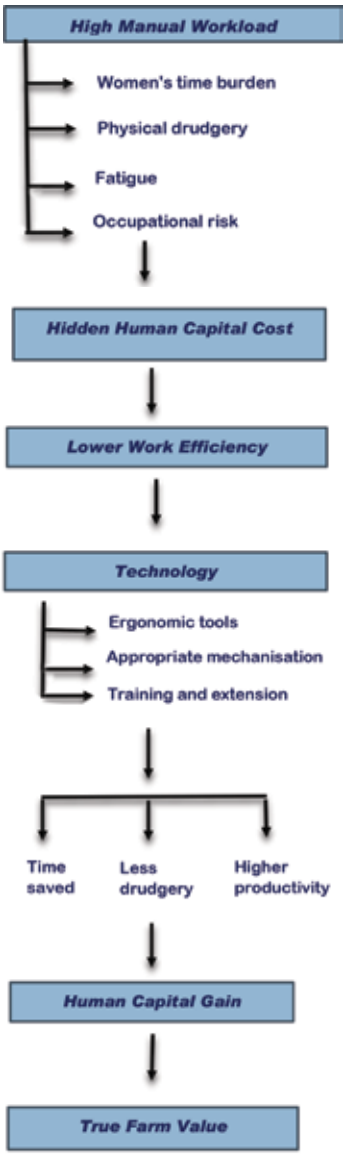
Net Human Capital Benefit = Labour-Time Savings + Productivity Gains + Avoided Health Costs − Technology Costs

While technology costs must factor in initial investment, fuel, maintenance, and training, the framework recognises that reducing physical drudgery acts as a direct investment in the farm's human balance sheet. This expands conventional technology assessment by auditing both crop output gains and worker capacity protection.

A technology should therefore not be evaluated solely on its purchase price and yield effect. Its impact on time, health, safety and gendered workload should also be incorporated into technology assessment.

From productivity accounting to human capital-adjusted productivity

Conventional agricultural productivity measures focus mainly on output relative to labour input. However, labour is not a uniform input. The same number of labour-days can involve very different levels of physical workload, fatigue, discomfort, and health



Pathway through which gender-sensitive and ergonomic technologies contribute to human-capital creation

risk. From a TVA perspective, agricultural productivity should therefore account not only for output but also for the condition and productive capacity of the people generating that output.

Human Capital-Adjusted Productivity = Agricultural Output ÷ (Labour Time × Workload Intensity × Health/Drudgery Burden)

This is initially a conceptual framework rather than a finalised empirical index. Its purpose is to recognise that productivity achieved through excessive physical strain may involve a hidden depletion of human capital.

Entrepreneurship as a driver of agricultural human capital

Agricultural entrepreneurship encapsulates a farmer's ability to innovate, manage risk, and optimise resource allocation, converting fundamental human capabilities into long-term productivity and resilience. This capability relies on an integrated pathway of physical and cognitive assets

Nutrition + health + knowledge + skills + agency + time → entrepreneurial capability → diversification + innovation + value creation.

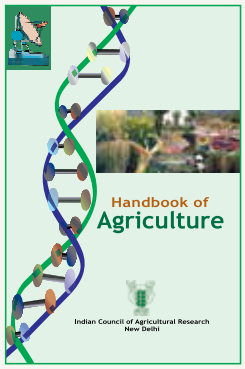
Conversely, severe physical drudgery, systemic malnutrition, and time poverty directly impair a farmer's capacity to pursue commercial opportunities. Mitigating these physical strains yields a distinct entrepreneurial dividend liberating time, safeguarding health, and expanding agency for high-value activities like crop diversification, processing, and localised marketing.

SUMMARY

True Value Accounting (TVA) evaluates systemic trade-offs by auditing how agricultural income impacts underlying capital assets. Empirical data reveal a critical sustainability paradox, farming systems often generate immediate financial returns while simultaneously liquidating human capital through physical exhaustion, musculoskeletal injuries, and severe time poverty. This bodily depreciation is highly unequal, with female and unpaid family workers bearing a disproportionate share of the strain from manual labour and poorly designed traditional tools. Conversely, integrating ergonomic technology and targeted mechanisation acts as a direct investment that lowers physiological costs and preserves long-term labour capacity. Ultimately, human health and physical longevity are productive assets rather than economic externalities; therefore, a farming system is truly sustainable only when it generates durable financial value without depleting the human capabilities that anchor agricultural livelihoods.

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