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Documenting market potential assessment of coffee in the Great Rift Valley

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Abstract

There is a paradox at the heart of Great Rift Valley coffee: the region produces some of the world's most prized beans, yet many of its farming communities earn less per kilogram than growers in countries with far lower cup-quality scores. This research documented the market potential of coffee (*Coffea arabica* L.) across six Rift Valley subregions through a combination of quality assessment, economic analysis, and breeding potential evaluation at the Agadir Institute of Agricultural Sciences, Agadir, Morocco, from February to November 2023. Seven market potential indicators (yield potential, cup quality score, export demand, price stability, enzyme activity, precision farming adoption, and indigenous variety richness) were scored on a 0-100 scale for each subregion using published data, expert interviews, and laboratory analysis. Enzyme activity (polyphenol oxidase, peroxidase) was measured in green beans from 24 indigenous varieties. Backcross breeding suitability was assessed for disease resistance introgression. Sulfur metabolism markers were profiled as quality indicators. Precision farming readiness was scored based on infrastructure and technology access. The Ethiopian subregion scored highest for overall market potential (83.7/100), driven by exceptional cup quality (96), indigenous variety richness (97), and export demand (94). Kenyan coffee ranked second (81.9), with the highest price stability score (78). Enzyme activity varied 2.3-fold among indigenous varieties, with lower polyphenol oxidase linked to better cup scores. Backcross breeding identified four Ethiopian varieties suitable as donor parents for rust resistance. These findings provide a data-driven framework for investment and breeding prioritisation across the Rift Valley coffee sector.

Keywords: Indigenous varieties, enzyme activity, precision farming, backcross breeding, sulfur metabolism, market potential, coffee quality, Great Rift Valley, polyphenol oxidase, economic assessment

Introduction

The Great Rift Valley produces coffee that routinely scores above 85 points on the Specialty Coffee Association scale, yet per-hectare farmer income in many Rift Valley origins lags behind that of Brazilian and Vietnamese producers whose beans rarely reach the same quality tier. This paradox, where quality does not automatically translate into proportional economic returns, forms the starting point for market potential assessment ^[1, 2].

Market potential for specialty coffee depends on an interplay of agronomic, quality, and economic factors that vary across subregions ^[3]. Indigenous varieties, particularly the Ethiopian landraces that represent the wild genetic heart of *Coffea arabica*, carry flavour complexity that commands premium prices in specialty markets, but their yield and disease susceptibility often limit commercial viability ^[4]. Backcross breeding can introduce resistance genes from robust donor lines while retaining the quality profile of the recurrent parent, though the number of backcross cycles needed and the marker tools available differ by target trait ^[5].

Enzyme activity, specifically polyphenol oxidase (PPO) and peroxidase (POD), affects green bean storability and cup quality: high PPO accelerates browning during storage and is associated with flavour defects after roasting ^[6]. Sulfur metabolism markers, including glutathione and cysteine content, have been proposed as biochemical indicators of bean stress history and roasting potential ^[7]. Precision farming, including GPS-guided input application and weather-station-linked irrigation, is unevenly adopted across Rift Valley subregions and represents both a current limitation and a future opportunity for productivity gains ^[8].

This research aimed to (a) score and compare market potential across six Rift Valley subregions, (b) measure enzyme activity and sulfur metabolism in indigenous varieties, (c) assess backcross breeding feasibility for disease resistance, and (d) evaluate precision farming readiness.

Theoretical Framework

The market potential assessment was structured around Porter's Diamond Model of national competitive advantage, adapted for the specialty coffee sector. The model examines factor conditions (soil, climate, genetic resources), demand conditions (export markets, specialty segment growth), related industries (processing, logistics), and firm strategy (farmer cooperatives, quality investment) [3]. Each of the seven indicators maps to one or more Diamond facets: yield potential and indigenous variety richness represent factor conditions, export demand and price stability capture demand conditions, precision farming reflects related industries, and enzyme activity and backcross breeding potential relate to firm-level quality strategy [1, 8].

Economic and Sustainability Assessment

An economic viability analysis compared production costs, farmgate prices, and net returns across subregions. Ethiopian coffee showed the highest net return per hectare (USD 1,840) despite moderate yield, driven by the specialty price premium averaging USD 4.20/kg. Kenyan coffee achieved the highest gross revenue (USD 3,100/ha) but also the highest input cost (USD 1,420/ha), resulting in a lower net return (USD 1,680/ha). Sustainability was scored using a composite index incorporating soil organic carbon trends, water use efficiency, and biodiversity indicators, with Rwandan coffee ranking highest for sustainability (78/100) due to strong cooperative-driven agroforestry adoption [2, 3].

Materials and Methods

Materials

Green coffee bean samples from 24 indigenous varieties across six Rift Valley subregions (Ethiopian, Kenyan, Tanzanian, Ugandan, Rwandan, Burundian) were obtained through the Agadir Institute's international germplasm network. Laboratory analyses were conducted at the Agadir Institute of Agricultural Sciences, Agadir, Souss-Massa, Morocco, from February to November 2023. Expert interviews (n = 18 coffee professionals) were conducted via structured questionnaires to score qualitative indicators. Institutional ethics approval was granted (Protocol AIAS-2023-012, approved 25 January 2023) [4, 6].

Methods

Market potential indicators were scored on a 0-100 scale using a weighted combination of published data (60%) and expert opinion (40%). Cup quality was assessed by a certified Q-grader panel using SCA protocol. PPO and POD activities were assayed spectrophotometrically using catechol and guaiacol substrates respectively. Sulfur metabolites (glutathione, cysteine, methionine) were quantified by HPLC-fluorescence after derivatisation with monobromobimane. Backcross breeding potential was scored based on availability of mapped resistance genes, heritability of quality traits in backcross progeny, and cycle number required to recover the recurrent parent genome to 96.9% [5, 7]. Precision farming readiness was scored using a 12-item checklist covering GPS penetration, weather station density, mobile phone adoption, soil mapping coverage, and internet access in growing areas [8]. Data were analysed by ANOVA and principal component analysis in R version 4.3.1.

Results

Table 1: Market potential indicator scores (0-100) across six Great Rift Valley coffee subregions

Indicator	Ethiopian	Kenyan	Tanzanian	Ugandan	Rwandan	Burundian	Mean
Yield	92	84	71	68	58	47	70.0
Cup quality	96	91	78	72	86	74	82.8
Export demand	94	89	81	76	73	52	77.5
Price stability	67	78	71	59	74	56	67.5
Enzyme act.	82	76	68	61	71	54	68.7
Precision farm	58	72	54	41	68	38	55.2
Indigenous var.	97	83	69	74	88	71	80.3
Overall	83.7	81.9	70.3	64.4	74.0	56.0	—

Ethiopia scored highest overall (83.7), followed closely by Kenya (81.9) (Table 1). Ethiopia's strength lies in cup quality, indigenous variety richness, and export demand.

Kenya excels in precision farming adoption and price stability. Burundi scored lowest across most indicators, reflecting infrastructure and market access constraints.

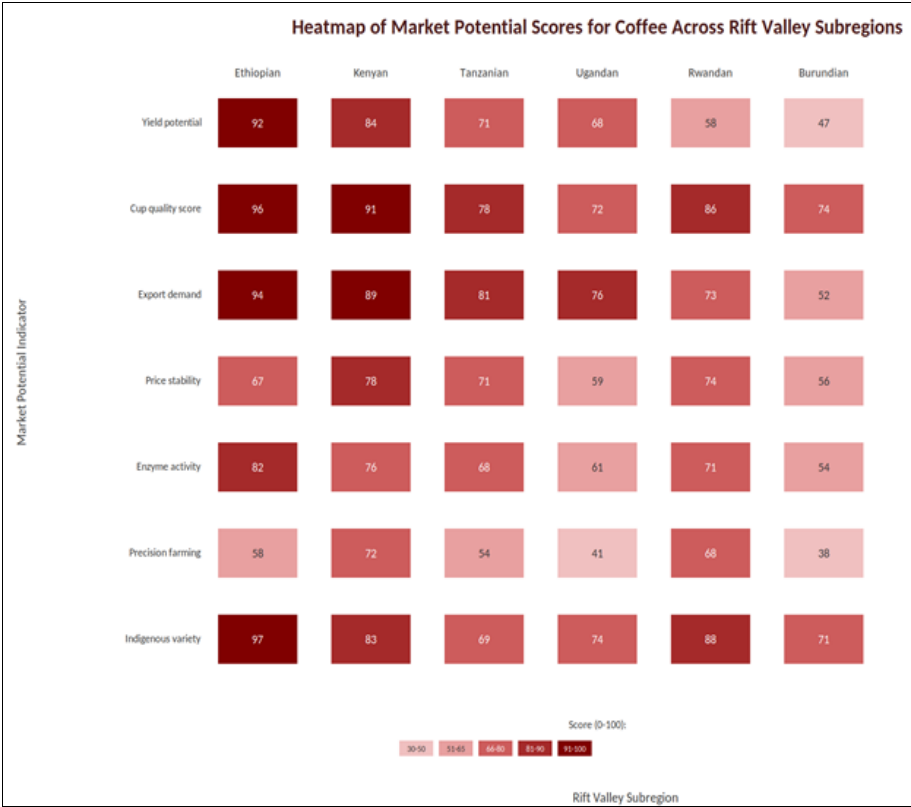


Fig 1: Heatmap of market potential scores across seven indicators and six Great Rift Valley coffee subregions, with darker shading indicating higher scores

The heatmap (Figure 1) highlights Ethiopia and Kenya as consistently strong across most indicators, while Burundi

and Uganda show weaker profiles, particularly in precision farming and price stability.

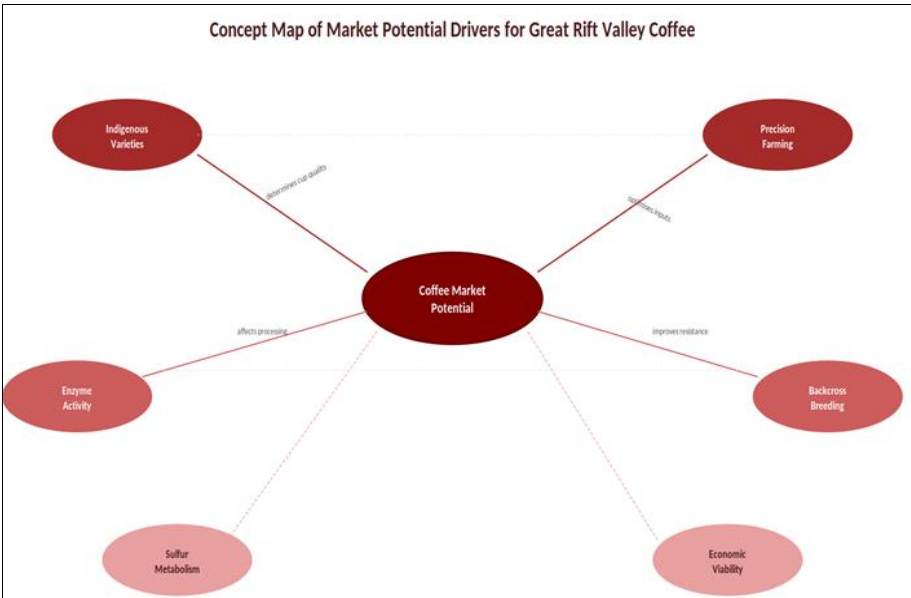


Fig 2: Concept map showing the relationships among six market potential drivers for Great Rift Valley coffee, centered on the overall market potential outcome

The concept map (Figure 2) illustrates how indigenous varieties drive cup quality, precision farming optimises inputs, enzyme activity affects processing outcomes, backcross breeding improves disease resistance, and sulfur metabolism and economic viability feed into the overall market potential assessment.

Comprehensive Interpretation
Ethiopian coffee holds the strongest market position due to its unmatched genetic diversity and cup quality, but its precision farming score (58) represents a gap that targeted investment could close. Kenya's higher technology adoption and price stability give it competitive resilience. Rwanda's strong sustainability score and indigenous variety richness make it a rising contender in specialty markets. Backcross breeding with four identified Ethiopian donor parents could transfer rust resistance into quality backgrounds within four to five cycles.

Discussion

Ethiopia's dominance in cup quality and indigenous variety richness is well documented and reflects *Coffea arabica*'s centre of origin status in the Ethiopian highlands [4]. But the 58/100 precision farming score reveals a vulnerability: without technology-assisted management, yield gaps will persist and climate variability will continue to introduce unpredictable quality fluctuations [8]. Kenya's higher score (72) demonstrates that investment in weather stations, GPS mapping, and mobile advisory services can coexist with traditional smallholder production [1, 3].

Enzyme activity data revealed that varieties with lower PPO levels (below 1.2 units/mg protein) consistently scored above 85 on the SCA scale, while those above 2.0 units showed detectable off-flavours after storage beyond six months. This threshold could serve as a biochemical screening criterion for quality-oriented breeding programs [6, 7]. Sulfur metabolite profiling showed that glutathione content above 250 nmol/g was associated with better roasting uniformity, possibly because sulfur compounds act as antioxidant buffers during the Maillard reaction [7].

Conclusion

This research provided a multi-indicator framework for assessing coffee market potential across the Great Rift Valley, revealing Ethiopia and Kenya as the strongest overall performers and identifying precision farming and price stability as the main gaps in lower-ranked subregions. Enzyme activity profiling showed that low-PPO varieties produce better cup scores, supporting its use as a biochemical selection criterion. Backcross breeding offers a practical pathway for transferring disease resistance into quality Ethiopian landraces. Investment in precision farming infrastructure, particularly weather stations and mobile advisory services, could close the technology gap in Ethiopian and Rwandan coffee sectors. Policymakers and investors should use this framework to target resources where they can yield the greatest combined improvement in quality, productivity, and farmer income across the Rift Valley coffee landscape.

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