

OPTIMIZATION OF PRODUCTION INPUT USAGE IN COCOA FARMING IN POLEWALI MANDAR REGENCY: A DATA ENVELOPMENT ANALYSIS APPROACH

Dian Asri^{1*}, Ummy Qalsum²

Agribisnis/ Universitas Samudra, Langsa, Aceh, Indonesia

Manajemen Agribisnis / Universitas Syiah Kuala, Banda Aceh, Aceh, Indonesia

E-mail: dian.asri@unsam.ac.id

Received: 04/08/2026 | Revised: 15/08/2026 | Accepted: 02/09/2026 | Published: 23/09/2026

Abstract

Although the adoption of superior cocoa clones has been widely expanded, the economic efficiency of cocoa agribusiness at the farm level remains heavily dependent on farmers' precision in managing and allocating production inputs rationally. In Polewali Mandar Regency, smallholder cocoa farmers face liquidity constraints and capital shortages while simultaneously exhibiting substantial input waste, particularly in the excessive and unbalanced application of chemical fertilizers. This study evaluates real physical input allocations compared to the Indonesian Coffee and Cocoa Research Institute (ICCRI/Puslitkoka) agronomic recommendations, identifies operational returns to scale, and analyzes input slack movement using Data Envelopment Analysis (DEA) under Variable Returns to Scale (VRS). The results reveal that farmers cultivating superior Sulawesi 1&2 clones achieve higher scale efficiency (54.54% Constant Returns to Scale / CRS) compared to local clone farmers (46.30% CRS). Input slack reaches its peak among 16–20-year-old trees, reflecting psychological over-fertilization during natural yield declines. Notably, 21–25-year-old Sulawesi 1&2 trees rehabilitated via side-grafting achieved complete zero-slack condition, operating on the efficient frontier, whereas local clones of the same age maintain significant input excess. Rationalizing input allocation and substituting excessive nitrogen/phosphate with essential potassium (KCl) are critical strategies for resource optimization.

Keywords: *Data Envelopment Analysis, input allocation, resource optimization, slack movement.*

INTRODUCTION

Cocoa (*Theobroma cacao* L.) is one of the most strategic plantation commodities supporting Indonesia's agricultural export earnings and serving as the primary source of livelihood for millions of rural smallholder households (Assoua et al., 2022; Wessel & Quist-Wessel, 2015). In West Sulawesi Province, the cocoa plantation sector plays a crucial role in the regional economic structure, contributing approximately 59% to the Gross Regional Domestic Product (GRDP) and absorbing more than 50% of the rural workforce (Central Bureau of Statistics [BPS], 2016). Nevertheless, smallholder cocoa plantations in Polewali Mandar Regency remain trapped in low actual productivity. The average yield of cocoa farmers in this region ranges from only 0.54 to 0.65 tons per hectare, lagging far behind the plant's optimal biological potential of 1.50 to 2.00 tons per hectare (Directorate General of Plantations, 2016; Susilo, 2015).

This low productivity stems from a combination of technical and managerial issues at the farm level, such as aging tree populations, low adoption of cultivation innovations, infestations of the Cocoa Pod Borer (CPB, *Conopomorpha cramerella*) and Black Pod rot (*Phytophthora palmivora*), as well as the misallocation of physical production factors (Kolapo et al., 2024; Purnomo et al., 2025). To halt the declining yield trajectory and rejuvenate unproductive farms, the government launched the National Movement for Cocoa Production and Quality Enhancement (Gernas Kakao). One of its primary intervention packages was the rehabilitation of old trees through side grafting techniques introducing superior national clones, namely the Sulawesi 1 and Sulawesi 2 clones. Biologically, these superior clones have proven superior in local agroclimatic adaptation, high yield capacity, and strong resistance to vascular streak dieback (VSD) disease compared to unselected local clones (Suryani, 2021; Susilo, 2015).

Although the adoption of superior clones has expanded, the economic efficiency of cocoa agribusiness at

the farm level (on-farm) remains determined by farmers' precision in managing and allocating production inputs rationally (Purnomo et al., 2025). On one hand, farmers in Polewali Mandar Regency frequently complain about liquidity constraints and capital limitations for purchasing production inputs (Asri et al., 2019; Danso-Abbeam & Baiyegunhi, 2020). On the other hand, maintenance practices in the field demonstrate evident input wastefulness: farmers tend to apply chemical fertilizers excessively and in an imbalanced manner without considering plant absorption requirements (Indonesian Coffee and Cocoa Research Institute [ICCRI / Puslitkoka], 2018). The traditional mindset assuming that higher doses of inorganic fertilizer will always yield higher harvests has triggered allocative inefficiency and wasteful farm production costs (Kolapo et al., 2024; Tsakok, 2021).

Previous studies on cocoa farming efficiency have largely measured aggregate technical efficiency scores and farmers' socio-demographic factors (Aneani & Ofori-Frimpong, 2018; Danso-Abbeam et al., 2020). However, most of these studies have not provided practical guidelines regarding quantitative targets for reducing input excess (input slack) per tree age group without decreasing total output. This study fills this empirical gap through three main foci: (1) evaluating farmers' real physical input allocation compared to ICCRI agronomic recommendations; (2) identifying operational scale of production (returns to scale); and (3) analyzing input slack movement values in depth to formulate rationalization and cost-saving strategies for smallholder cocoa farming in Polewali Mandar Regency.

LITERATURE REVIEW

The theoretical foundation of modern production efficiency analysis is rooted in the formulation of the production frontier, which measures the capacity of Decision-Making Units (DMUs) to avoid resource wastefulness (Farrell, 1957; Førsund, 2018). Technical efficiency is defined as managerial capacity to produce maximum output from a given quantity of physical inputs (output orientation) or to minimize the input quantities required to produce a specified output volume (input orientation) (Coelli et al., 2005; Kumbhakar et al., 2015). In smallholder plantation farming, which frequently faces capital liquidity constraints and rising market fertilizer prices, an input-oriented efficiency approach is highly relevant for guiding cost rationalization and production cost reduction without sacrificing harvest yields (Danso-Abbeam & Baiyegunhi, 2020; Kuswanto et al., 2023).

In contemporary agricultural economics literature, frontier efficiency measurement methods are dominated by non-parametric linear programming approaches in the form of Data Envelopment Analysis (DEA) (Charnes et al., 1978; Cooper et al., 2002; Kuswanto et al., 2023). DEA possesses strong analytical advantages over parametric models because it does not require specifying a particular functional form for production (such as Cobb-Douglas or Translog functions) and is not bound by restrictive statistical error distribution assumptions (Kuswanto et al., 2023; Ramanathan, 2006). Under the Variable Returns to Scale (VRS) assumption, the DEA model can construct a flexible empirical piecewise frontier, identify best-practice peer benchmarks, and compute input slack values with precision (Banker et al., 1984; Ramanathan, 2006). Slack analysis enables researchers to quantitatively measure the extent of physical resource excess in inefficient units that can be directly eliminated without altering the actual output level (Kuswanto et al., 2023).

Various empirical studies on cocoa farming in developing countries demonstrate that physical production factors particularly inorganic fertilizers, synthetic pesticides, and human labor inputs frequently experience substantial technical and allocative inefficiencies (Kolapo et al., 2024; Aneani & Ofori-Frimpong, 2018; Danso-Abbeam et al., 2020). In Indonesia, the implementation of side grafting rehabilitation technology utilizing local and introduced superior clones has proven to accelerate the recovery of aging smallholder cocoa orchards (Suryani, 2021; Susilo, 2015). Nevertheless, the success of newly grafted canopies in producing pods heavily depends on the accuracy of fertilization doses and the pruning of productive branches (Purnomo et al., 2025; Suryani, 2021). Applying chemical fertilizers beyond the root absorption capacity of plants triggers financial waste in farming operations and leaves chemical residues in orchard soils (Kolapo et al., 2024; Tsakok, 2021). Therefore, integrating DEA slack modeling with commodity-specific agronomic fertilization standards provides a robust evaluative basis to guide the optimization of production factor allocation at the smallholder plantation level.

METHOD

This study was conducted in Polewali Mandar Regency, West Sulawesi Province, focusing on two cocoa-producing center sub-districts: Anreapi Sub-district and Mapilli Sub-district. The selection of locations was carried out purposively, considering that both areas were concentrated target regions for the Gernas Kakao side-grafting rehabilitation program and possessed adequate representation of both superior and local clone farms. Primary data collection was conducted through structured interviews using questionnaires with farmer respondents during the 2025 harvest season. The target population of the study comprised smallholder cocoa farmers managing plant stands

within the productive age range of 5 to 25 years. Sample determination was carried out using purposive sampling with a total of 109 respondents, categorized into two farming groups: (1) 55 farmers applying side-grafting technology with superior Sulawesi 1 and Sulawesi 2 clones; and (2) 54 farmers cultivating local cocoa clones without side grafting. Quantitative analysis was performed using an input-oriented Data Envelopment Analysis (DEA) model under the Variable Returns to Scale (VRS) assumption (Banker et al., 1984; Coelli et al., 2005; Kuswanto et al., 2023). The linear programming model for each i -th farmer respondent is formulated as follows:

$$\begin{aligned} &\text{Min } \theta, \lambda \quad \theta \\ &\text{Subject to:} \\ &- y_i + Y\lambda \geq 0 \\ &\theta x_i - X\lambda \geq 0 \\ &NI'\lambda = 1 \\ &\lambda \geq 0 \end{aligned}$$

Where θ is the technical efficiency score of the i -th farm unit ($(0 \leq \theta \leq 1)$); y_i is the output vector of the i -th farmer; x_i is the physical input vector of the i -th farmer; Y and X represent the output and input matrices of the entire sample (109 farmers), respectively; λ is the weighting vector for peer benchmark units; and $NI'\lambda = 1$ is the convexity constraint reflecting the VRS assumption. The output variable (Y) is total dry cocoa bean production (kg/ha/season). The physical input variables (X) encompass six elements: (1) Urea fertilizer (kg/ha); (2) SP-36 fertilizer (kg/ha); (3) KCl fertilizer (kg/ha); (4) manure/organic fertilizer (kg/ha); (5) chemical pesticides (liters/ha); and (6) human labor input (labor-days/ha), combining family labor (TKDK) and hired labor (TKLK).

Excess factor allocation was evaluated using input slack movement values. A farm unit operates at full technical efficiency if it achieves a score of $\theta = 1$ and all input slacks equal zero (zero-slack condition). A negative slack value indicates the quantity of input that can be reduced for the farmer to reach the efficient frontier without sacrificing harvest output. Furthermore, actual fertilizer allocation performance was evaluated comparatively against standard technical dosing guidelines for recommended fertilization by plant age published by the Indonesian Coffee and Cocoa Research Institute (ICCRI / Puslitkoka, 2018).

RESULTS AND DISCUSSION

Input Allocation Performance and Fertilization Discrepancies

Smallholder cocoa farming in Polewali Mandar Regency is characterized as labor-intensive and utilizes production inputs intensively. The majority of farmers cultivate self-owned land with moderate farm sizes (0.50 to 2.00 hectares). Table 1 summarizes the average actual allocation of production inputs per hectare per year for Sulawesi 1&2 superior clone and local clone farms.

Table 1. Average Input Usage in Cocoa Farming in Polewali Mandar Regency

Production Input Type	Unit	Sulawesi 1&2 Clones (n = 55)	Local Clones (n = 54)
Manure / Organic Fertilizer	kg/ha	1.110,11	734,83
SP-36 Fertilizer	kg/ha	195,54	45,86
TSP Fertilizer	kg/ha	7,00	15,54
Urea Fertilizer	kg/ha	48,89	18,37
Compost Fertilizer	kg/ha	36,67	0,00
Biofarm / Liquid Organic Fertilizer	liters/ha	0,56	0,46
Total Labor Input	labor-days/ha	27,00	27,51

Based on the data in Table 1, farmers using Sulawesi 1&2 clones applied manure (1,110.11 kg/ha) and SP-36 fertilizer (195.54 kg/ha) in far greater quantities than local clone farmers (734.83 kg/ha and 45.86 kg/ha, respectively). This condition is directly linked to the responsiveness of side-grafted plants, which feature denser canopies and high pod-load potential, thus demanding intensive macro-nutrient supply (Suryani, 2021; Susilo, 2015).

Regarding labor, local clone farming absorbed slightly higher labor input (27.51 labor-days/ha) compared to superior clones (27.00 labor-days/ha). This is influenced by irregular planting spacing and branch architecture of local cocoa, requiring extra labor for weed control and maintenance pruning.

When compared against ICCRI (2018) technical standards, a sharp fertilization gap is evident at the farmer level. According to standard recommendations, the annual fertilizer requirement for mature cocoa trees (>5 years) ranges from 0.178–0.222 kg Urea, 0.105–0.207 kg SP-36/TSP, 0.200–0.332 kg KCl, and 7.30 kg organic fertilizer per tree. In the field, on fertilized farm plots, average Urea application reached 9.35 kg per tree for Sulawesi 1&2 clones and 12.90 kg per tree for local clones, indicating an extremely high dosage excess. Conversely, the application of potassium fertilizer (KCl) is widely neglected by farmers due to capital constraints and relatively high prices, despite Potassium being vital for bean weight development and pod resistance against black pod disease infection.

Scale of Production Conditions in Cocoa Farming (Returns to Scale)

A comparison between Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) DEA model estimations maps the operational scale position of cocoa farming based on tree age groups, as presented in Table 2.

Table 2. Economic Scale Distribution of Cocoa Farming Based on Tree Age Groups

Tree Age (Years))	Sulawesi 1&2 Clones (%)			Local Clones (%)		
	CRS	DRS	IRS	CRS	DRS	IRS
0 – 10	7,27	0,00	3,64	7,41	0,00	3,70
11 – 15	18,18	0,00	12,73	12,96	0,00	16,67
16 – 20	12,73	0,00	27,27	16,67	0,00	22,22
21 – 25	16,36	0,00	1,82	9,26	0,00	11,11
Total (%)	54,54	0,00	45,46	46,30	0,00	53,70

The analytical results in Table 2 show that no cocoa farm plots operate in the decreasing returns to scale zone (DRS = 0.00%). Most farming units operate under constant returns to scale (CRS) or increasing returns to scale (IRS). In Sulawesi 1&2 clone farming, 54.54% of plots have achieved optimal scale efficiency (CRS), whereas in local clones, the proportion of CRS is lower at 46.30%. The presence of plots operating under IRS (45.46% in superior clones and 53.70% in local clones) indicates that farms have not yet reached optimal production scale. In the IRS zone, proportional and technically managed additions of inputs have the potential to yield greater harvest output increases (Kolapo et al., 2024; Danso-Abbeam et al., 2020). This demonstrates that the main bottleneck to productivity stems not from small farm size, but from sub-optimal input allocation across managed plots

Input Slack Analysis and Resource Optimization Potential

Excess physical production factor usage was measured through the input-oriented DEA model's slack movement values. Table 3 presents the average input slack values for Sulawesi 1&2 clone and local clone cocoa farming across various plant age strata.

Table 3. Average Input Slack Values in Sulawesi 1&2 Clone and Local Clone Cocoa Farming

Input Variable	Sulawesi 1&2 Clones				Local Clones			
	0–10 yrs	11–15 yrs	16–20 yrs	21–25 yrs	0–10 yrs	11–15 yrs	16–20 yrs	21–25 yrs
Urea Fertilizer (kg/ha)	-10,25	-9,50	-27,11	0,00	0,00	-20,32	-29,10	-22,10
SP-36 Fertilizer (kg/ha)	-15,64	-13,38	-29,60	0,00	-7,42	-20,36	-65,00	-11,38
KCl Fertilizer (kg/ha)	0,00	-2,28	-26,89	0,00	0,00	-2,73	-24,88	-6,73
Organic Fertilizer (kg/ha)	0,00	-0,65	-22,74	0,00	-5,55	-1,35	-6,39	-9,36
Chemical Pesticide (liters/ha)	-0,16	-6,57	-4,45	0,00	-0,22	-0,85	-2,01	-2,80
Labor Input (labor-days/ha)	0,00	-1,24	-1,51	0,00	-1,33	-0,60	-2,35	-0,75

The estimation results in Table 3 indicate that input inefficiency occurs across nearly all production variables, with the largest waste concentrated in inorganic fertilizers SP-36 and Urea. The peak of input excess occurs in tree stands aged 16–20 years. In this age group, local clone farming recorded an average SP-36 slack of -65.00 kg/ha, Urea of -29.10 kg/ha, and KCl of -24.88 kg/ha. Meanwhile, for Sulawesi 1&2 clones in the same age group, SP-36 excess reached -29.60 kg/ha and Urea reached -27.11 kg/ha.

The high slack values at age 16–20 years reflect farmers' psychological compensation when facing the natural decline in mature tree harvest yields. When plant productivity begins to shrink, farmers tend to react by excessively increasing chemical fertilizer doses. However, due to aging root systems and overly dense canopies, this fertilizer supply cannot be biologically utilized by the plants. Consequently, the excess fertilizer turns into a deadweight cost that widens technical inefficiency gaps (Kolapo et al., 2024; Tsakok, 2021).

In contrast, a highly positive achievement is observed in Sulawesi 1&2 clone plants aged 21–25 years, where all input variables record a slack value of 0.00 (zero-slack condition). This proves that old trees rehabilitated through the side-grafting technique using Sulawesi 1&2 clones are capable of operating precisely at the optimal technical efficiency frontier (efficient frontier). Farmers in this group possess mature managerial skills in managing water sprout pruning and fertilizer dosing, so all nutrients are fully absorbed by the productive grafted scions (Suryani, 2021). Conversely, local clone orchards of the same age (21–25 years) still experience excess usage of Urea by 22.10 kg/ha and SP-36 by 11.38 kg/ha.

For the labor variable, slack ranges from 0.60 to 2.35 labor-days/ha, reflecting a surplus of family labor (TKDK) that has not been effectively utilized in weeding and pest control activities. By reducing this physical input wastefulness, farmers can significantly cut farming costs without reducing harvest yields, while reallocating labor hours to high value-added post-harvest activities such as cocoa bean fermentation.

CONCLUSION

This study concludes that smallholder cocoa farming in Polewali Mandar Regency continues to face

allocative inefficiency in physical production inputs. The application of inorganic fertilizers, particularly Urea and SP-36, is proven to exceed ICCRI agronomic recommendation standards and generate substantial input slack values, with peak wastefulness occurring in trees aged 16–20 years. Farming with superior Sulawesi 1&2 clones demonstrates significantly more efficient resource allocation compared to local clones, characterized by lower slack values and the achievement of full technical efficiency (zero-slack condition) in rehabilitated old trees aged 21–25 years.

These findings provide practical recommendations for cocoa farmers to reduce Urea and SP-36 fertilizer dosages according to slack values without concern of decreasing harvest yields. Cost savings from reducing excess fertilizer can be reallocated to purchasing Potassium (KCl) fertilizer, which has been widely neglected, as well as improving orchard sanitation. For agricultural extension agencies and policymakers in Polewali Mandar Regency, future advisory interventions should prioritize location-specific balanced fertilization guidance and the acceleration of side-grafting rehabilitation using Sulawesi 1&2 clones to rejuvenate unproductive smallholder cocoa orchards.

REFERENCES

- Aneani, F., & Ofori-Frimpong, K. (2018). "An analysis of yield gap and some factors of cocoa (*Theobroma cacao* L.) yields in Ghana", *Sustainable Agriculture Research*, Vol. 2 No.4, pp.117–127.
- Asri, D., Rifin, A., & Priatna, W. B. (2019). "Efisiensi teknis usaha tani kakao berdasarkan klon Sulawesi 1&2 dan klon lokal", *Jurnal AGRISEP: Kajian Masalah Sosial Ekonomi Pertanian dan Agribisnis*, Vol.18 No. 1, pp. 75–88.
- Assoua, P. C. M., Kpenavoun Chogou, S., Degbey, C. H., & Gandonou, E. (2022), "Impact of sustainability certification on the economic and social performance of cocoa farmers in West Africa", *International Food and Agribusiness Management Review*, Vol. 25 No. 4, pp. 629–646.
- Badan Pusat Statistik [BPS]. (2016). *Sulawesi Barat dalam Angka 2016*. BPS Provinsi Sulawesi Barat.
- Banker, R. D., Charnes, A., & Cooper, W. W. (1984), "Some models for estimating technical and scale inefficiencies in Data Envelopment Analysis", *Management Science*, Vol. 30 No. 9, pp. 1078–1092.
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978), "Measuring the efficiency of decision making units", *European Journal of Operational Research*, Vol.2 No.6, pp. 429–444.
- Coelli, T. J., Rao, D. S. P., O'Donnell, C. J., & Battese, G. E. (2005), *An Introduction to Efficiency and Productivity Analysis* (Edisi ke-2). Springer Science Business Media.
- Cooper, W. W., Seiford, L. M., & Zhu, J. (2002). *Data Envelopment Analysis: History, models, and interpretations*. Dalam W. W. Cooper, L. M. Seiford, & J. Zhu (Eds.), *Handbook on Data Envelopment Analysis* (hal. 1–39). Kluwer Academic Publishers.
- Danso-Abbeam, G., Ehiakpor, D.S., & Aidoo, R. (2020), "Agricultural extension and its effects on farm productivity and income : insight from Northern Ghana", *Agriculture & Food Security*, Vol.9 No. 11.
- Danso-Abbeam, G., Baiyegunhi, L.J.S., & Ojo, T.O. (2020), "Gender differentials in technical efficiency of Ghanaian cocoa farms", *Heliyon*, Vol. 6 No. 2, pp. 1-11.
- Direktorat Jenderal Perkebunan. (2016). *Statistik Perkebunan Indonesia 2013–2015: Kakao*. Direktorat Jenderal Perkebunan.
- Farrell, M. J. (1957), "The measurement of productive efficiency", *Journal of the Royal Statistical Society: Series A (General)*, Vol.120 No.3, pp. 253–290.
- Førsund, F.R. 2018. "Multi-equation modelling of desirable and undesirable outputs satisfying the materials balance," *Empirical Economics*, Springer, Vol. 54 No.1, pp. 67-99.
- Kolapo, A. M., Oseni, J. O., & Adewumi, M. O. (2024), "Sustainable intensification of cocoa production under a changing climate: Evaluating adoption, yields, and farm-level impacts in Southwest Nigeria", *Frontiers in Sustainable Food Systems*, Vol.8, pp. 1505454.
- Kumbhakar, S. C., Wang, H. J., & Horncastle, A. P. (2015). *A Practitioner's Guide to Stochastic Frontier Analysis Using Stata*. Cambridge University Press.
- Kuswanto, K., Asmara, R., & Budiwitjaksono, G. S. (2023), "Taking a deeper look at the priority of agricultural industry efficiency through the use of data envelopment approach", *Agroalimentaria*, Vol.29, pp.167-177.
- Purnomo, B. H., Novita, E., At-Ta'anny, U., & Suryaningrat, I. B. (2025), "The eco-efficiency level analysis at various scales of robusta coffee production of Argopuro mountain based on life cycle assessment (LCA)", *Pelita Perkebunan (a Coffee and Cocoa Research Journal)*, Vol.41 No.1, pp. 36-46.
- Pusat Penelitian Kopi dan Kakao Indonesia [Puslitkoka]. (2018). *Pedoman Teknis Budidaya dan Pasca Panen Tanaman Kakao*. Pusat Penelitian Kopi dan Kakao Indonesia.

**OPTIMIZATION OF PRODUCTION INPUT USAGE IN COCOA FARMING IN POLEWALI MANDAR
REGENCY: A DATA ENVELOPMENT ANALYSIS APPROACH**

Dian Asri **et al**

- Ramanathan, R. (2006). "Evaluating the comparative performance of countries of the Middle East and North Africa: A DEA application", *Socio-Economic Planning Sciences*, Vol. 40 No.2, pp. 156–167.
- Suryani, I. (2021), "The development technique of side and budwood grafting improving production of cocoa in Mamuju Regency West Sulawesi, Indonesia", *OnLine Journal of Biological Sciences*, Vol. 21 No.2, pp. 199–206.
- Susilo, A. W. (2015), "Bahan tanam kakao: Karakteristik klon unggul dan pengembangannya di Indonesia". *Warta Pusat Penelitian Kopi dan Kakao Indonesia*, Vol.27 No.1, pp.1–9.
- Tsakok, I. (2021), "Towards a fertilizer policy for smallholder agriculture in Sub-Saharan Africa. Policy Center for the New South", *Policy Paper*.
- Wadud, A., & White, B. (2000), "Farm household efficiency in Bangladesh: A comparison of stochastic frontier and DEA methods", *Applied Economics*, Vol.32 No.13, pp.1665–1673.
- Wessel, M., & Quist-Wessel, P. M. F. (2015), "Cocoa production in West Africa, a review and analysis of recent developments", *NJAS: Wageningen Journal of Life Sciences*, Vol.74 No.5, pp.1–7