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SUSTAINABILITY AND GENDER IMPLICATION OF TEA HARVEST MECHANIZATION IN WEST JAVA

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ABSTRACT. Indonesian tea industry has applied harvest mechanization to improve harvest productivity and profit due to a labor shortage. In order to maintain the sustainability of this mechanization, it is crucial to assess the balance of economic, environment, and social impact of the mechanization. This study aims at exploring the sustainability of mechanization in three tea industries in Indonesia using sustainability intensification (SI) indicators framework. Drawing on the case of three tea plantations industry in the West Java, this study applied a descriptive exploratory qualitative method. Data were collected through participant observation, in depth interviews, and focus group discussions. Data were analyzed using five domains of sustainability intensification (SI) indicators, namely productivity, economic, environment, human, and social domain. Findings of this study suggest that tea harvest mechanization increases productivity and economic profit, although the usage of fuel to operate the machine has contributed to the air pollution in the plantation area. Tea harvest mechanization also improve human domain by increasing workers household income. In social domain, it strengthens social capital among workers and promotes the formation of a new gender division of labor which is more inclusive. In order to enhance sustainability of mechanization in Indonesian tea industry, it is crucial to re-design the technology into a more gender friendly, increase women's capacity and access to resources, re-assure gender balance and equity in group work, and strengthen sustainable Occupational Health, and Safety (OHS) programs.

Keywords: gender; harvest; mechanization; sustainability; tea

KEBERLANJUTAN DAN IMPLIKASI GENDER DARI MEKANISASI PANEN TEH DI JAWA BARAT

ABSTRACT. Industri teh Indonesia telah menerapkan mekanisasi panen untuk meningkatkan produktivitas panen dan keuntungan karena kekurangan tenaga kerja. Untuk menjaga keberlanjutan mekanisasi ini, sangat penting untuk menilai keseimbangan dampak ekonomi, lingkungan, dan sosial dari mekanisasi tersebut. Penelitian ini bertujuan untuk mengeksplorasi keberlanjutan mekanisasi di tiga industri teh di Indonesia dengan menggunakan kerangka kerja indikator sustainability intensification (SI). Dengan mengambil kasus di tiga industri perkebunan teh di Jawa Barat, penelitian ini menggunakan metode kualitatif deskriptif eksploratif. Data dikumpulkan melalui observasi partisipan, wawancara mendalam, dan diskusi kelompok terarah. Data dianalisis dengan menggunakan lima domain indikator intensifikasi keberlanjutan (SI), yaitu produktivitas, ekonomi, lingkungan, manusia, dan sosial. Temuan dari penelitian ini menunjukkan bahwa mekanisasi panen teh meningkatkan produktivitas dan keuntungan ekonomi, meskipun penggunaan bahan bakar untuk mengoperasikan mesin telah berkontribusi terhadap polusi udara di area perkebunan. Mekanisasi panen teh juga meningkatkan domain manusia dengan meningkatkan pendapatan rumah tangga pekerja. Di ranah sosial, mekanisasi memperkuat modal sosial di antara para pekerja dan mendorong terbentuknya pembagian kerja baru yang lebih inklusif. Untuk meningkatkan keberlanjutan mekanisasi di industri teh Indonesia, sangat penting untuk mendesain ulang teknologi yang lebih ramah gender, meningkatkan kapasitas dan akses perempuan terhadap sumber daya, memastikan keseimbangan dan kesetaraan gender dalam kerja kelompok, dan memperkuat program Keselamatan dan Kesehatan Kerja (K3) yang berkelanjutan.

Kata kunci: gender; keberlanjutan; mekanisasi; panen; teh

INTRODUCTION

Mechanization refers to the act or process of causing a task to be performed or operated by machinery. The machine powered by animals, fossil fuels, and electricity to replace the usage of simple hand tools and human power. In farming, mechanized indicates by use, access, and adoption of mechanized tools. The term "use" refers to applying a mechanical resource to increase productivity at the individual or household level; while 'access' refers to availability of mechanical resources at an individual, household, or community level; and the 'adoption' means

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the frequent use of mechanical resources by an individual, household, or community (Peterman et al., 2014).

In agricultural sectors, there are various reasons underlying mechanization; such as labor scarcity during harvest time in rural areas, work time effectiveness, increased labor and land productivity (Purwantini & Susilowati, 2019); intention to maintain product quality (Buchori et al., 2018; Triana et al., 2020); inequality in meeting demand and supply (Tittonell & Giller, 2013), the availability of low-cost machine tools from developing countries (Agyei-Holmes, 2016), and transformation of traditional agriculture to a modern one that assumed to be more efficient and effective hence changing the business culture (Pusat Sosial Ekonomi Dan Kebijakan Pertanian (PSEKP), 2016).

In Indonesia, the decreasing interest of young workers to participate in agriculture works in rural areas has become the main drive for mechanization (Susilowati 2016). In the tea plantation industry in Indonesia, mechanization is a strategic option for tea plantation owners to increase their labor productivity and harvest due to labor shortage and aging workers. Mechanization in tea plantation industry has shifted the mode of production from labor-intensive to technology intensive to improve business efficiency and competitiveness (Solahuddin, 2018). According to Olmstead and Rhode (2014, p. 168), mechanization means "… involved the replacement of simple hand tools and human power by more complicated machinery powered by animals, fossil fuels, and electricity."

Despite its versatile capability to replace human's workforce, mechanization has faced sustainability issue. In order to maintain sustainability, it is crucial assess and monitor agricultural mechanization using sustainability indicators. There are frameworks to assess the sustainability of mechanization. Houmy et al., (2013) suggested three principles of mechanization sustainability, namely economic viability, social equity, and environmental resilience. Economic viability aspect measures the impact of mechanization by means of economic value such as increased output, so the farmers and the other stakeholders (retailers, distributors, manufacturers, importers, and service providers) are able to meet their living needs. Social equity aspect differs to the farmers' point of view. However, in general, this aspect refers to the benefits that are received by farmers in the social context, such as their status in their neighborhood. The last principle of mechanization sustainability suggested by Houmy et al. (2013) is environmental resilience which refers to a chance for the new protection method of the environment and its resources as a result of the mechanization.

On the other hand, Musumba et al., (2021) and Fischer et al. (2018), recommend more elaborate indicators by introducing indicators of mechanization sustainability in five domains: 1) productivity, 2) economic (labor profitability and market participation), 3) environmental (biodiversity and pollution), 4) human (nutrition, health, and capacity to experiment), and 5) social (gender equity, social cohesion, and collective action). In the agricultural context, mechanization productivity is measured by the total output of farming activities (annual harvest, crops of non-grain production, and animal-derived products). Economic domains measure the mechanization by calculating the incomes and expenses produced by the mechanization process; the sale of the farming products in the market; labor availability; and its impact to the welfare of the surrounding community. Environmental domains refer to land conservation, vegetation and insect diversity, pest levels, the availability of natural resources, and the disasters and pollution that might come as a result of mechanization. Human domains measure the mechanization by food availability and how it provides good nutrition; and human health that might be damaged because of the interaction of humans with the animals. This domain also concerns the household capacity to hold an experiment with a technology. Social domains measure the mechanization by its impact to the gender equity, social cohesion, and collective action in the agricultural process. From two frameworks, Musumba provides more practical means to consider multiple dimensions of sustainability.

It is important to assess the sustainability of mechanization from several angles. Food and Agriculture Organization (FAO) states that sustainable mechanization can concurrently develop value chains and food systems. Sustainable mechanization can enhance post-harvest, processing, and marketing activities, as well as making them environmentally and gender friendly.

Mechanization is part of sustainable development (Sims et al., 2016), socially embedded, and highly gender sensitive (Van Eerdewijk & Danielsen, 2015). Thus, mechanization has a great effect on gender. In

some cases, it has changed the pattern of labor allocation and ease women's workload (Bank et al., 2009). However, there are cases when new agricultural technologies that were expected to ease female workload bring additional tasks and more burden in harvest and post-harvest activities (Doss, 2001). Also, there are innovations of technology that benefits men more than women by reducing men's workload while increasing women-related activities (Kingiri, 2010). Therefore, the global diffusion and adoption of new technology must be examined using gender perspectives to ensure gender equity. It consider how both gender can access or have control of resources invested in mechanization technology from design, implementation and monitoring evaluation. Attention to gender related issues is a key strategy for promoting gender equality (Caglar, 2013). Recently, there are resurgence to emphasize gender equity and sustainability in mechanization (Houmy et al., 2013; Pingali, 2007; Van Eerdewijk & Danielsen, 2015); as women failure to adopt new technology are usually due to different gender needs and preferences (Doss, 2001).

Indonesia has committed to achieve Sustainable Development Goals (SDGs) in all sectors, including the tea plantation sectors. Therefore applying sustainable mechanization in agricultural development is important best practices of SDG (Filho et al., 2019). It is crucial to ensure the sustainability in the mechanization could also promote gender equity among workers. In the tea plantations industry, the impact of mechanization on the change of gender-based participation and gender division of labor is vivid. Tea harvest had been the domain of female workers for a long time because of their nimble finger skills to pick high quality shoots. Thus, tea picking had become women's path to participate in public domain work to earn income for their family although it also give them double burden, both in domestic (household) and public (work) domain (Kusumawati, 2013). In many cases, tea picking also establish vulnerability and injustice for female tea pickers who has double burden and mostly from poor family (Chandra & Fatmariza, 2020). The introduction of tea harvest machine has opened up this domain for male worker and has changed the system of tea picking work. Originally, manual or semi-mechanical picking done individually by 15-20 female pickers, while machine picking should be done by group consists of 5 male and female operators. The terms "picking machine operators" then has become popular to replace the previous term 'pickers' which refers to the use of hands or picking scissors.

There are two development tea harvest machines, i.e. single picking machine type 90 and double picking machine type 120. Single machine type 90 still seldom adopted in tea plantation in Indonesia because it required higher cost than double machine type 120. So far, single picking machine still covered by manual plucking, while the existence of double picking machine has shape a new group for its machine operator. The new group composition in the tea harvest mechanization has created a new gender division of labour as both male and female workers have similar opportunity to participate in harvest. Female operators will probably loose their opportunity to join group if this new technology is no longer appropriate for them. Such as when the picking machine type 120[1] is used, more male operators is needed because the machine is a way heavier and not comfortable for female body. As the consequence, gender inequality in mechanized tea harvest will sharply emerge and female participation in harvest will dramatically decrease (Sita, 2019).

Tea mechanization exists to drive sustainable tea production with more high productivity but also consider efficiency. Drawing on the phenomenon of harvest mechanization in the tea industry in Indonesia, this study aims at exploring the mechanization sustainability using five Sustainability Indicator (SI) by Musumba et al., (2021) and Fischer et al. (2018) framework that provide more practical indicator means. It also explore the impact of this SI to gender equity among workers in the three tea plantation areas in West Java.

METHOD

This study applied descriptive qualitative method with a phenomenological approach. The research sites were three areas of tea plantations in West Java-Indonesia, Gambung, Ciater, and Sedep Tea Plantation (see Figure 1). Gambung and Sedep is highland tea garden located at the altitude above 1200 m above sea level (asl), while Ciater is medium land tea plantation located at 800 – 1200 m asl. These sites were chosen because they are pioneers in applying tea picking mechanization technology in West Java. Participants of this study were women and men

[1] Picking machine

working in the tea plantation as machine pickers or plucking machine operators. The research took place on 2021.

Figure 1. Map of Study Area
Source: Adoption from Google Map, 2021

Data were collected through observation, documentation, interviews to total 39 participants (12 tea pickers in Gambung, 11 tea pickers in Ciater, and 16 in Sedep), and Focus Group Discussions (FGD) was conducted once in each research areas (Manager of tea garden/ plantation, Mandor/foreman, tea picker: machine and manual). Data were analyzed based on 5 sustainability indicators (Sustainability Intensification /SI Indicator (Musumba et al., 2017 and Fischer et al., 2018): productivity, profitability (labor, income), environmental aspects, human resources, and social aspects. Gender analysis framework were applied to analyze activity profile, access, and control of work (Handayani et al., 2008). Qualitative data analysis consisted of three stages, data reduction, presentation, and conclusions. Triangulation techniques on various sources such as people, time, and space to ensure consistent and saturated data collection were applied to ensure data validity (Huberman & Miles, 2002; Moleong, 2007).

Process of mechanization in tea harvesting in research areas are relatively the same. Since the first time after the nationalization of plantations from The Dutch, tea was picked by hand plucking with 25 tea pickers in one group. Then in early 2000, it started picked by scissors as semi-mechanized tea harvesting with 15-20 tea pickers in a group, then around the beginning of 2010 there is first trial mechanization tea harvesting with single machine type 90 and double machine type 120 but in practically, mostly now double machine used in tea plantation, include in research areas.

Research participants in Gambung were mostly women (62,5%), in Ciater mostly men (70%), and in Sedep mostly women (80%) (see Table 1). Mostly the education level of participants are elementary school: in Gambung 86%, in Ciater 65%, and in Sedep 77%. Generally, the gender proportion of tea machine pickers is 1:3 (male:female). The research subjects were selected purposively based on their willingness to join research voluntarily (Cresswell, 2013). The characteristic of age participants can be seen in Table 1.

Table 1. The characteristic of research participants

Age	Tea Plantation					
	Gambung		Ciater		Sedep	
	Women (%)	Man (%)	Women (%)	Man (%)	Women (%)	Man (%)
≤ 30	0	12.5	0	14.3	0	0
31-40	12.5	12.5	0	28.6	33.3	16.7
41-50	50.0	12.5	14.3	28.6	33.3	0
≥ 50	0	0	14.3	0	16.7	0
Total	62.5	37.5	28.6	71.4	83.3	16.7

Source: Processed by researchers

RESULTS AND DISCUSSION

The profile of sustainability intensification (SI) at three tea plantations industry based on five domains are as follow:

Productivity

Machine picking produces more leaves and wider coverage area per day than hand/manual picking. Although both machine and hand/ manual picking picked the shoots when the tea bush "flushes" or called *manjing petik* in local term, the machine picking required a certain height. The quantity and quality of tea shoots from machine picking has been influenced by several factors; such as the skills of the picking machine operator to operate the machine, the condition and quality of the picking machine tool, the picking field condition, which vary depending on plant material and age, the slope of the land, tree cover, OPT (plant-disturbing organisms), and climate/season. In terms of work quality, machine picking produce coarser shoots than manual and semi-mechanical plucking that is carried out selectively, which is the buds and top leaves.

The plucking machine tool used in the three tea plantations are mostly made in Japan, the 120

GT type, either Ochiai or Kawasaki brand. These two brands have been known for its durability and the spare parts are easy to find. However, the weight of these machines about 16.5 kilogram, heavier than those made in China, such as Sangyang brand which is only 15 kilogram.

Unlike the conventional selective hand picking, tea harvesting with machine is done collectively in a group. One group consists by 4-5 persons, male and female. Two persons operate the machine, one person holds the tea bag, one person collect the leaves, and one person to sortation the leaves from weeds. They can take turn among each other. The work results are divided equally among the persons in the group. The productivity of both gender groups is relatively the same. The picking machine and how to use it in a group are described in Figure 2.

Figure 2. Ochiai brand plucking machine and tea picking activities with a plucking machine

Source: Researchers documentation

Using a manual/semi-mechanical plucking method using scissors, a picker could produce a minimum of 60 kg shoots per day while using a plucking machine, pickers could obtain an average yield of 150 kg shoots per day. The summary of system and work capacity describe in the Table 2 below.

Table 2. The system and work capacity of the machine picking group

Work System	Description
Number of pickers per group	4-5 people
Working days	6 days (Monday - Saturday)
Working hours	06.00 - 13.00 is divided into shoots/weights 1 starting at 06.00-09.00 and picking/ weighing 2 starting at 10.00-13.00. One hour (9 am-10 am for a break).
Type of worker	Permanent employees; PKWT (Temporary employee); Wholesale power.
Wage system	Minimum standard of daily work; Wholesale.
Wages	Rp.380 - 600/kg shoots.
Distribution of wages	Based on the results of group work, which are divided equally.
Machine picking group working capacity	Flat-moderate land: 1 -1.5 quintals/day; Sloping/steep land: 5 - 6 quintals per day.
Individual work capacity	80 - 200 kg shoots/day or an average of 150 kg shoots/day.
Weighing frequency	2 (two) shoots weighing.
Plucking Tools	The GT 120 type plucking machine varies, such as the Kawasaki Brand; Ochiai; dear. The dominant picking machine used is the Ochiai brand.
Fuel	2 stroke system with gasoline (petalite) mixed with oil.
Picker work equipment	Head protection, body armor, boots, and gloves.
Picked hanca location (area) in one day	The picking location starts where the location is already mostly designed for picking using a plucking machine.
Picking cycle	Varies in the range of 35 - 90 days depending on the population and age of the pruning year (TP).
Flush production (high)	The “Kulir” system (picking at holiday)

Source: Processed by researchers

Profitability

Profitability refers to how tea harvest mechanization technology could change gender work relations and economic benefits received directly by female and male picking laborers.

Labor

There is a large participation of women in tea picking activities. In the three gardens, most of the machine-picking work was conducted in a group consist of male and female to the ratio 2:1, respectively. However, there were also machine-picking group activities with all-male or all-female pickers. When using a plucking machine, women could play a role in all activities. However, most of them are assigned to hold the shoot bags rather than hold the machine. Male were mostly engage in picking/returning tools, starting machines, and operating the machine. The division of labor in tea harvest differs from the previous labor pattern at tea plantation industry where women had dominant role in manually/semi-mechanically picking (Table 3. and Figure 3).

Table 3. Tea harvesting activity profile with a tea picking machine

Activity	Who is doing the activity?				
	M	W	M>W	W>M	W=M
Picking plucking tools from storage.	X	X	X		
Picking up a net from storage.	X	X			X
Picking up fuel from the orchard office.	X				
Switch on the plucking tool.	X	X	X		
Operating the plucking tool.	X	X			X
Being a plucking tool operator.	X	X	X		
Holding balloon shoots on a plucking machine.	X	X		X	
Gathering shoots.	X	X			X
Selecting shoots.	X	X		X	
Carrying shoots.	X	X			X
Weighing shoots.	X	X			X
Recording and weighing results.	X	X			X
Refining shoots.		X			
Cleaning picking hallway.	X				
Returning plucking tools to the orchard office.	X	X	X		
Fixing plucking tools.	X				
Fixing balloon shoots on plucking tools.	X	X		X	
Preparing food/ supplies.	X	X		X	

Notes:

M: Man worker

W: Women worker

M>W: Predominantly carried out by man workforce

W>M: Predominantly carried out by women workforce

W=M: Balanced/ women and man can do equally

X: Check list

Source: Processed by researchers

Based on the study conducted by Sita (2019), the machine-picking group relay had interesting facts. The plucking machine operators consisting of women only produced a stable and durable performance, in contrast to plucking machine operators consisting of men only. However, fatigue complaints and aches resulting from the physical workload are felt more by female operators and can be at risk of MDS's issue. Below is a statement of a female plucking machine operator in Ciater Gardens (NI): *"The back often aches… and the feeling of soreness is pronounced, especially when I first held the plucking machine compared to plucking with scissors…."*

This condition could limit the chances of tea plantation entrepreneurs providing job opportunities for women in tea picking activities to maintain the work productivity of tea shoots. However, this opportunity needs emphasis on machine-picking group engineering, such as the application of operator combinations and strengthening the application of K3 (occupational health and safety) for machine-picking workers. Lack of opportunities for women in tea harvesting activities will be marginalized if the design of the plucking machine tool is gender-unfriendly and far from the needs and preferences of women (Doss, 2001). Contrarily, the condition is worsened by the current shortage of tea pickers with most of them retiring. The following is the expression of the foreman picking the machine at Ciater Tea Plantation (JT): *"...Nowadays, many pikers are retiring and it is difficult to find new ones, especially those from junior high school/ high school. Therefore, sometimes retired pickers (scissor pickers) are still employed. Currently the scissors foreman supervises only 14- 15 pickers, in contrast to the previous number of 25 pickers per foreman. The average education is only elementary school graduates."*

Figure 3. Machine picking group activity with the proportion of the combined workforce (male as a machine operator, female as balloon/shoot bag holder)

Source: Researchers documentation

Patriarchal culture still places men above women in access and control over resources, especially in cases where tea plantations are located in rural areas with medium-high plains. This also occurs in the three research gardens,

particularly machine picking activities (Sita & Herawati, 2017). Women still experience difficulties accessing education/training, technology, tools, and careers, although trusted with money-related matters (loans/credits), which are connected to women's domestic roles (see table 4.) Access to communication services, health, savings/cooperatives, and worker wages have been "balanced" between women and men in the workplace. According to relative results of women's work, access to education and skills for plucking machine technology should be open for w\omen, especially those who have previously worked as scissors pickers. This will ensure equitable and sustainable gender relations in tea harvesting activities.

Table 4. Workforce Access and Control Distribution

Workforce Access and Control Distribution	Who can access it?				
	W	M	W>M	M>W	W=M
a. Informal education (training and mentoring)		X			
b. Cultivation technology	X	X		X	
c. Information technology (mobile phones, etc.)	X	X			X
d. Plucking tools		X			
e. Health	X	X			X
f. Savings	X	X			X
g. Credit/Loan	X	X	X		
h. Career path	X	X		X	
i. Wages	X	X			X

Notes:

M: Man worker

W: Women worker

M>W: Predominantly accessed by man workforce

W>M: Predominantly accessed by women workforce

W=M: Balanced/ women and man can do equally

X: Check list

Source: Processed by researchers

Earnings

Income generated by a machine picking laborer is from weighing the number of shoots per day. Daily, weighing is done twice, except during flush or minus seasons, when the frequency of weighing the shoots is different. The average shoots yielded per day by the machine picking group was 1 ton, while on flat - medium land, it goes up to 1.2 tons - 1.5 tons of shoots per day. On a slopy and steep land, it ranges from 5-6 quintals of shoots per day, suppose it is equally divided per machine picking group member it is approximately 80 - 200 kg shoots/day, depending on the season.

From the results of these productions, the income received by machine picking workers ranged between Rp. 50,000 and Rp.150,000 per day. The monthly income of machine-picking workers ranged between Rp. 1.000.000 and Rp.3.000.000 and more if the season is flush or on flat land conditions, hence, pickers tend to get premium picks. Workers who were scissors pickers earned much higher than machine picking laborers. A male picking machine operator at Sedep Tea Plantation (BD) stated: "*... There was once a maximum number of shoots, and the income per machine could be up to Rp. 1.2 million per day or approximately Rp. 250,000 per person per day… premiums are rarely obtained in steep gardens….*"

The income generated working as a machine picking laborer supports the family's daily needs. In case of excess income, it is invested in livestock, stall business, or saved through cooperatives. Often, the income caters to medical expenses of fatigue and aches resulting from machine picking activities. Furthermore, the income is promising and benefits for the tea harvest workers and their families. Nonetheless, the income is divided equally as a form of collective work. This demonstrates that there is no gender discrimination in relation to the provided income. However, another aspect such as the risk level of work has implications on gender relation inequality. For example, the workload received by women is greater than that of male workers. The double burden born by working women, especially from low-income families, will limit their ability to enjoy the benefits of this work unless gender-friendly tea harvesting technology is developed. Different from the case of coffee picking, study found that there is a significant relation between gender inequality and payment of minimum wages, earned leave, weekly off with wage, bonus as per rate, and entitlement to provident fund and medical facilities, which is further compounded by the plantation size factor (Chattopadhyay, 2020). In general, women are more likely to be working in sectors where the gender wage gap and unexplained wage gap, commonly attributed to discrimination, is higher,

but in tea picking machine group wage are the same for male and female worker, because of collective work pattern.

Environment

The environmental indicator shows data from the tea picking machine technology related to the tea shoots quality picked by tea picking machines. Although this technology produces quality shoots (medium picking), gasoline (*pertalite*) and oil picking machines produce smoke contaminating the picked tea shoots and causing oil spillages on tea lands. Mostly, in tea picking machine group, men worker showed have more responsibility on fuel for tea picking machine than women worker. Consequently, skills and supervision in tea picking procedures are critical while using a picking machine. The research related to pollution caused by tea harvesting machines is still scarce; so that more research needs to be conducted on carbon emissions from machine picking activities.

Tea plantations designed to use plucking machines to shade trees should be greatly minimized to prevent the occurrence of machine-picking operational difficulties. This could also pose hazards related to machine-picking performance leading to field-related accidents. Therefore, the role of protective trees and the environment around tea plantations functions optimally. The arrangement of protective trees in gardens designed for machine picking should be considered. Plant diversity around a sustainable tea garden helps to provide sustainable oxygen, convenient for tea pickers working in the tea garden.

Recently, environmental issue in tea plantation has become challenges to face of climate change and global warming, including in Indonesia, climate change has caused extreme weather, drought, flood, and pest dynamics in tea plantation. Study Heryana and Rokhmah (2021) showed that Indonesian tea plantation potential as CO_2 absorption, and the carbon stocks of tea plants depend on its elevations. Study on China, showed that in subtropical hilly tea plantation, the seasonal variations of CO_2 exchanges showed significant correlations with the seasonality of environmental variables, which indicated that the seasonal variations of CO2 exchange fluxes are affected by the seasonal variations of environmental factors (Pang et al., 2019). In future global warming may transform this subtropical tea plantation from a carbon sink to a carbon source. There were 18.78 Mt CO_2eq emissions from cultivation especially from fertilizer application, while there was a 7.71 Mt CO_2eq carbon sink of tea trees (He et al., 2022). For environment issue, for ecofeminist, stated that women are naturally more conserving of resources (Meinzen-Dick et al., 2014), and with the presence and percentage of women on the board of directors are positively associated with environmental disclosures (Chebbi et al., 2020).

Human Resources

The indicators of human resources in applying sustainable tea harvest mechanization technology relate to the capacity of men and women to operate tea picking machines. From the observations in the Gambung tea plantation showed that the working capacity of female picking machine operators was high and stable compared to male operators (Figure 4.) Therefore, the combination of female workers in one machine picking group could maintain a balance of machine-picking work capacities. Tea harvesting workers using picking machines could increase their work capacity compared to harvesting tea manually/semi-mechanically using picking scissors.

Figure 4. Female workers in operating picking machine

Source: Researchers documentation

However, tea harvesting workers using plucking machines are exposed to a higher-impact risk than manual/semi-mechanical tea harvesting using scissors. These impact risks include (1) Upper body muscle injury (musculoskeletal disorder/MSD)(A. H. Simarmata et al., 2020), (2) Work accidents resulting from plucking machine knives (K3), (3) Impaired hearing caused by noise from the plucking machine, especially in the driver and assistant positions (A. Simarmata et al., 2020) (4) Tripping on a slippery garden or high slope, and (5) Injuries related to tea trees/trunks in the picking tunnel. Based on observations in the field, female workers are more prone to muscle injury (MSD) resulting from the heavy load of operating machines. Same result study in Bhattacherjee et al., (2021) found that musculoskeletal morbidities among female

tea garden workers of Darjeeling India were found to be considerably high. The following is a statement made by a male plucking machine operator at Gambung Tea Plantation (I): "*... when holding the machine, the engine vibration is strong in the driver's position hence the hands shake….*"

These risks could be minimized by ergonomically repairing the machine picking tools for gender pickers in West Java. Dihingia & Dewangan, (2012) stated that MSD's symptoms can be reduced by implementing ergonomic interventions, reducing load carriage, improving work organization with job rotations and allowing sufficient rest during work to the tea pluckers. Assistance in designing and using ergonomic tea harvest machines also can increase productivity (Bhattacherjee et al., 2021). To strengthen work performance of machine picking and its groups structure can be done by (1) implementing work patterns with women and men combination (especially balloon holders) though women should be allowed as plucking machine operators, (2) training tea harvesters to boost the work capacity and skill operating picking machines, and 3) employing the suitable age bracket of workers to compensate for the work of the plucking machine. Below is a statement of a female plucking machine operator at Sedep Tea Plantation (IK): "*... Those in their 50s are definitely not strong and it feels hard to operate this machine, in their 40s they are already «running out»... different from picking scissors, those in their 50s are still strong enough to pick shoots that weigh more than 60 kg.*" If there's no ergonomic improvement to this machine, women tea pickers will be the ones to suffer the most.

Consequently, future studies should focus on increasing the number of pickers in process and applying mechanization technology for tea harvesting. This could be facilitated through (1) training groups on machine picking skills, (2) establishing better working environment conditions through manage a proper picking aisle for tea harvest machine so as to minimize the risk of the picker falling or tripping, (3) keep maintenance tea harvest machine to work optimally, and also maintain adequacy of tea shoot basket availability; (4) ensuring punctuality on the arrival of the top truck during the weighing process to reduce fatigue waiting in the field and (5) guaranteeing workers good health and safety while operating tea picking machines by periodic health checks.

Social

This domain relates to collective actions and conflict resolution in gender social relations during the application of mechanization technology for tea harvesting with picking machines. Based on results collected in the three gardens, various forms of social relations foster collective action and conflict resolution. This is due to changes in the work pattern of tea harvesting from being harvested manually/semi-mechanically with 15-20 members individually to harvesting with machines by 4-5 people members per group collectively.

Various collective actions and conflict resolution in the form of horizontal social relations between members of the picking machine group include (1) Maintaining cohesiveness and work comfort among members to obtain maximum performance results. (2) Sharing skills in operating picking machines to maintain maximum group performance. (3) The initiative to repair/replace damaged plucking machine tools independently (e.g., fan belts and balloons/ shoot bags). (4) Mutual borrowing of personal protective gears (apron/body cover) in case one does not have one. (5) Assistance with accessing loans to support workers' daily needs. (6) Moral and financial support in times of distress, (7) Sharing food/supplies among picking machine members. (8) Initiative to organize uniformity in dress code to show cohesiveness. For financial activity, such as loan and saving in group, mostly managed by women and many research showed that women more have ability to manage their funds. Even though women have more ability to manage/save the money, but for financial literacy women showing lower than men (Hasler & Lusardi, 2017) which caused by gender gap in education (Bannier & Schwarz, 2018).

Forms of vertical social relations in machine picking groups, between workers/members and the foreman/supervisor, include, (1) great work performance to retain their jobs, 2) retaining teammates, (3) communicating in case of an issue and the worker is unable to report, (4) proposing new members or substitutes in the group in case a member is absent, and (5) utilizing social media to communicate with superiors or fellow workers or share information and skills. Additionally, there is a "family cover" in vertical social relationships, where workers could ask family/relatives to replace themselves at work temporarily. The reason behind this is to secure job positions for sick workers or those retiring hence unable to carry out their work effectively.

Below is a statement made by a plucking machine operator who acted as «family cover» at Sedep Tea Plantation (N): "*... I only have 4 months left to work, "help" or replace my aunt who is sick and soon, 4 months from retiring... if I get called again, I want to work on picking machines again... see how...."*

This phenomenon enables the group to work and get results as usual normally. However, measuring and evaluating the performance of the machine-picking group (members) becomes difficult since it is not administratively recorded. Although with some consideration measures, women's participation and employment opportunities in tea harvesting activities are open. Currently, machine picking work is known to increase the self-confidence and existence of tea pickers (Sita, 2019b) and boost women's experiences in a new institution of tea harvesting activities.

Discussion

Tea plantation has been characterized by labor intensive (Wu, 2015; Yuliando et al., 2015) in which women done most of the work. Therefore, to invite women's participation in the tea industry, it is crucial to considers gender-based need in the development of tea mechanization technology. Such as women need a light weight and easy to operate machine more than men. The heavier the machine the more likely it is to increase the physical workload especially for female workers. They are prone to MSD's (Musculoskeletal Disorders). Lack of attention to women's need in technology design and access forecloses the possibility of enhanced farm productivity, especially for crops in which women play a predominant role (Hansda, 2017).

This new division of labor and the creation of new technologies in tea plantations tend to be reserved for men only. Fischer et al. (2018) showed that men has already dominated mechanized options. It caused by asymmetric communication structure are still firmly rooted in society (Lestari & Setiawan, 2020) which ultimately the potential for inequality in access to technology for women continues to occur in agriculture even though previously this work was dominated by women, i.e. harvesting process.

The application of mechanization technology for tea harvesting with picking machines is a strategy currently applied by large-scale tea plantation entrepreneurs in West Java to overcome declining performance and increase cost-efficiency. Sustainability Intensification (SI) indicators can be used holistically or as an interdisciplinary to evaluate the performance of mechanization technology for tea harvesting with picking machines and its gender implications.

The five sustainability Intensification (SI) indicators in the application of tea harvest mechanization technology provide an overview of the sustainability challenges and justice. Productivity indicator shows that technology could offer increased capacity, effectiveness, and higher work efficiency than manual (scissor) tea harvesting methods that are labor-intensive. Currently, there is very high labor competition in rural areas and men operating the typewriter.

The profitability indicator shows changes in the work pattern, from individual to collective ones. The division of labor between women and men has become more obvious because agricultural machinery technology is male-friendly. Although women are open to opportunities in all tea harvesting activities, they face greater challenges posed by the picking machine. This is because the picking machine is not ergonomically designed; hence gender access and control over resources are a men's duty because of the strong patriarchal culture in Indonesia. However, this technology offers an opportunity for women to earn more, motivating them to continue working optimally and improve their family welfare and contribution in the public sphere.

The environmental aspect showed that high-quality shoots could be produced, but with various notes considering optimal conditions for tea cultivation, tools, operators, and climate/weather. Since tea products are highly dependent on the quality of the raw material for shoots ("fresh leaf"), it is important to study environmental aspects. This is especially true regarding the results of fuel emissions and machine-picking activities to ensure this technology is environmentally friendly and sustainable. In contrast, picking/harvesting tea manually or "hand plucking" is environmentally friendly because it is done selectively using the female "nimble fingers" skill.

The human resource indicator showed that the work performance of men and women is balanced. However, the work capacity of picking machine operators, especially women, will show high performance if the design of the packing machine is more gender-friendly and is supported by a program to strengthen the capacity of the picking machine operator. Furthermore, tools and spare parts of the picking machines should be regularly serviced and replaced to ensure the

safety of workers. This will also minimize the risk of MSDs complaints and other K3 issues that affect workers' performance in the tea plantation fields.

The social aspect showed that machine-picking mechanization technology had given machine-picking institutions a new color. This technology has created positive forms of horizontal and vertical social relations manifested in various collective actions and conflict resolution between women and men in the work environment. Consequently, it has fostered more profitable motivation and work ethics, especially for women and tea plantation entrepreneurs.

The implication of this research regarding productivity, the approach may increase capacity, effectiveness, and work efficiency. In terms of profitability, it leads to collective work patterns, creating a new gender division of labor where access is open to men. However, this technology offers higher and fairer incomes for workers, including women. Environmentally, there is potential to produce quality shoots based on optimal conditions, including plant cultivation, tools, operators, and climate/weather. Although the work capacity is quite balanced, picking machine operators, especially women, may improve performance in case the design of the picking machine is more gender friendly. Furthermore, machine picking technology revolutionized tea picking institutions in various social relation aspects both vertically and horizontally. This relates to collective action and conflict resolution, which is beneficial for women. Furthermore, women's participation in technology is still open through combined work patterns. Efforts to enhance sustainability include improving the technology of tea harvesting machine tools that are more gender friendly and ergonomic, increasing women's capacity and access to resources, applying engineering work patterns with gender equity, and strengthening sustainable Occupational Health and Safety (OHS) programs.

CONCLUSION

Other research implications are applying agricultural mechanization with gender perspective within sustainable agricultural development is the main reason for creating best practices of Sustainable Development Goals (SDGs), especially SDG 5 in achieving a gender equality and empower all women and girls, include in participation on agriculture sector. This research would be very beneficial for gender organizations in national and global on better designing, implementing, and monitoring evaluation of gender mainstreaming programs. Future studies should focus on sustainability in tea harvesting mechanization technology that are gender-related in tea machine picking households, development of social networks for women workers and gender-sensitive education and training, and repair or modification of picking tools, tea harvesting machines and work systems in tea gardens with gender and ergonomic perspective, and environmental impacts. Other research for the future should give strong attention on the power relationship in the change from non-machine jobs to machine-based jobs.

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