USE OF WEARABLE TECHNOLOGY

TO OBSERVE GENDER DIFFERENCES IN WORKLOAD IN FARMING HOUSEHOLDS IN INDONESIA

a feasibility study

NOVEMBER 2018

Suggested citation: Sathiyakumar R., Berlo S., Ayoola I., Davey R., Stewart T., Pangestu D., Salmaso G (2018). *Use of wearable technology to observe gender differences in workload in farming households in Indonesia: a feasibility study.* Health Research Institute, University of Canberra.

CONTENTS

EXECUTIVE SUMMARY

Recent advances in technology offer the potential to monitor and quantify physical activity and workload in communities or individuals in 'real time' and in 'place' through GPS, activity wearables and smartphones. Despite the increased use of such devices in time-motion studies in a variety of work context, most of what is known about the work patterns of men and women in rural farm settings has been through the use of self-report surveys, time diaries and focus groups. Very few studies have employed objective measures.

As a first, this feasibility study aimed to test the use of activity wearables (data capture — Garmin wrist devices), smartphone apps', data transmission and GPS geolocation, to measure objectively workload, physical activity and mobility patterns in a group of Indonesian rice farming households in Besah, Bojonegoro district.

Participant engagement was high as was daily adherence to using the technology for 5 months over an agricultural cycle that included; preparation, planting, harvesting and drying.

Objective data were collected from 30 rice farming households (30 men and 30 women) and included: heart rate, step counts, sleep, distance travelled, and locations visited. Focus groups were used to compare objective measures with self-report and to help validate measures.

Data triangulated from the objective measures and focus groups show some correlation with aspects of workload division and activity/mobility patterns, although more research is required to test the reliability of perception-based methodologies. Key findings include;

- Men make more frequent trips to the paddy field and other places than women, possibly because they have several jobs, whereas women travel further distances from their village (may be to visit relatives).
- Women spend more time at the house and undertake much more manual work in the house while men rest at home.
- Overall men have higher step counts than women, so presumably walk further.
- Workload/physical activity 'intensity' as measured by time spent in the different heart rate zones, is higher for both men and women in the paddy fields than anywhere else (more demanding manual work is done in the field than the home).
- The percentage of waking time spent in the different categories of 'light', 'moderate' and 'high/vigorous' activity is similar for men and women. Overall, women have similar workloads to men and even more in the home (domestic chores and looking after family).

The main advantages to using the wearables and smartphone technology were: being able to objectively and remotely monitor at both an individual and community level, 'real-time and place' surveillance and quantify in detail workload, physical activity and mobility patterns throughout the day/season.

This has great promise in future to monitor the impact of changes in agricultural practice or policy at the individual or community level.

Objective data were collected from 30 rice farming households.

1. INTRODUCTION

Market systems development programmes, like the Australian Department of Foreign Affairs and Trade (DFAT) Australia-Indonesia Partnership for Rural Development (AIP-R), seek to address the root causes that prevent poor farming households from effectively participating in and benefitting from markets. AIP-R invest in strengthened interactions between market players (private and public sector) and farming households (themselves also market players), for example by facilitating business models that foster the buying and selling of agricultural inputs or transmitting key practice information.

In line with their intentional value creation for the poor, they also seek opportunities to empower women and stimulate positive gender equality outcomes (AIP-Rural, 2018). This is approached from a 'do-no-harm' perspective i.e. so as to avoid increasing women's workload or reducing their agency, and from a mainstreaming and women targeted perspective such as specifically targeting constraints that inhibit women's empowerment.

Strategically this means considering six domains of economic empowerment in the design, implementation and monitoring of interventions (AIP-R,2017).

1. Economic advancement — increased income and/or improved return on labour
2. Access to opportunities and life chances such as skills development, jobs or market linkages
3. Access to assets, services and needed support to advance economically
4. Decision-making authority in different spheres including household finances
5. Manageable workloads through efficiency, innovation and support
6. Women's greater agency through leadership roles and networking opportunities

Accordingly, AIP-R integrates women's economic empowerment (WEE) into the design of interventions in a number of ways. Firstly by diagnosing the underlying constraints to the equitable inclusion of women in markets; secondly by engaging with market actors to incorporate greater inclusion through market-driven models that are also beneficial to them, and thirdly by ensuring that results measurement data are gender disaggregated and collected with sufficient timeliness and frequency as to allow for adjustments to be made to avoid doing harm and maximise positive outcomes, as well as by incorporating specific indicators against the six domains (Jones, 2016).

1.1 BACKGROUND

Agriculture is the primary source of income and employment for rural subsistent populations in most of the developing countries (FAO, 2011). Historically, agriculture has been conceptualised as a male-dominated sector, and most of the literature has focused on men and their roles, responsibilities and health issues (FAO, 2011, Habib et al., 2014). However, all over the world women contribute enormously to rural development, and several studies have reported that women play more dominant (indeed prominent) roles in agricultural production and the rural economy in developing countries than men (Chiong-Javier, 2009). As a result of male outmigration from rural areas and the growth of commercial farming, women's roles in agriculture are expanding in many countries (FAO, 2017), with significant consequences for food systems and rural societies at large, meaning that the share of women in agricultural employment is expected to grow even further.

Farming is considered a hazardous occupation for men and women in developing countries (Habib et al., 2014). Most of the farming activities such as ploughing, irrigating, weeding and harvesting are physically demanding tasks which often cause severe consequences including health problems, for example, musculoskeletal problems, chest pains and miscarriage (Osborne et al., 2011). It can be argued that the impact of work on family life is more significant for women than for men and that women are burdened with the greater share of the toil and hardship underlying rural development.

It has been reported that women often spend more time in producing crops, engaging off-farm employment, tending livestock, home gardening and performing domestic activities such as childcare, food preparation, collecting water/ firewood, while men spend more time undertaking business transactions, buying farm equipment and fertilizers and marketing (Brown, 2003, Bryceson and Howe, 1993, FAO, 2011, IFAD, 2016, Rahman, 1993). These daily activities of women are unpaid and not always considered as 'economically active employment' (IFAD, 2016, Mohammed, 2014, Singh and John, 2017). Further, women often work long hours in farming seasons compared to non-farming seasons (Nag and Chintharia, 1985). However, methods used to assess occupational workload and labour division have relied almost exclusively on self-reported surveys, interviews and observation methods.

Understanding the specific gender differences of household and occupational workloads of farming men and women is important in evaluating the long-term impact of agricultural practices and changes in practice, especially from a development context. For example, some interventions to improve practice may lead to unintended adverse changes in the workload of women and men which can affect their well-being and overall quality of life (World Bank, 2012). Similarly, development programs can leverage their understanding of time and workloads constraints to design interventions to make workloads more manageable, or goods and services more accessible.

Indonesia is an agrarian country where 60% of citizens depend on agriculture as their primary occupation (Su Mustaffa and Asyiek, 2015). Farming remains a meaningful livelihood for rural Indonesian farmers to alleviate their poverty burden (DFAT, 2013). In Indonesia, men are commonly considered as household heads and primary breadwinners, whereas the contribution of women are perceived as supplementary, and they are perceived as supporters of their husbands (Siegmann, 2007). Conversely, field observations and research across AIP-R interventions suggest that perception does not match the reality on the ground, as women are highly involved in farming activities, significantly contribute to households' incomes as well as being disproportionately responsible for reproductive activities e.g. child bearing and rearing; household maintenance, including cooking and fetching water and fuelwood; and caring for elderly and sick family members. The nature of woman's role as a worker is often described using the triple burden concept of 'breeder-feeder-producer' (Boulding 1976). This gender division of labour often prevents women from realizing their full potential.

The Department of Foreign Affairs and Trade (DFAT) of Australia has been supporting rural Indonesian farmers and providing sustainable economic growth for several decades (DFAT, 2013, DFAT, 2014). AIP-Rural commenced its latest project in 2013 to support smallholder farmers and offer sustainable market-oriented solutions for agricultural constraints in Indonesia (AIP-Rural, 2018, DFAT, 2013). Under the AIP-Rural program, four projects (PRISMA, TIRTA, SAFIRA and ARISA) are implemented with the support of managing contractors Palladium, Swisscontact and Australian research institute CSIRO (AIP-Rural, 2018).

Palladium is an international company in the design, development and delivery of positive impact to create social and economic value. Palladium has commissioned the University of Canberra in collaboration with Onmi design (who provided technical support) to undertake this feasibility study.

1.2 RESEARCH PROBLEM TO BE ADDRESSED

Gathering accurate and objective data on occupational workload, labour productivity and division of labour among men and women within households and agricultural enterprises is challenging. Due to the difficulty in directly observing women and men for an extended duration, methodologies mostly rely on focus-group discussions, household surveys based on recall and time-use diaries. These address the profile of workers, such as age, sex, characterization of the work process and duration of activities performed by the workers, according to the work type and workload (duration/frequency) recognized by the workers, and occupational accidents. Time diaries and physical activity questionnaires can be used to provide a detailed record of how people perceive and allocate their work time during the day, often focusing on specific farming activities relevant to the research in question (Crosbie, 2006).

However, these methods are expensive, time-consuming and suspected to be fairly inaccurate, partly because they are based on preconceived gender norms, often by both the men and women of the home, as well as those collecting the data who are subject to biases (Shephard, 2003), and also because they are self-reported (Crosbie, 2006, Shelton and John, 1996). Furthermore, these methodologies often set historical rather than real-time benchmarks, meaning that they are not especially good for tracking changes that may arise from changing conditions e.g. the introduction of irrigation or a labour-saving technology which would change the household cropping pattern or the workload intensity.

There are very few studies that have attempted to assess occupational workload objectively among rural farm workers, and no studies have been identified in Indonesia.

1.3 EQUIPMENT USED IN THE STUDY

The advent of smartphones and wearable activity sensors affords the opportunity to make direct objective, empirical observations of respective activity levels and locations in 'real time'. Monitoring and measuring objectively the intensity of physical activity and location where activity occurs potentially allows inferences to be drawn as to the nature of the activity. For example, moderate activity in the location of farmland is likely to be agricultural related; in contrast, lighter activity in the location of the house is likely to be household related. Examples of potential indicators of workload and activity patterns that could be monitored include:

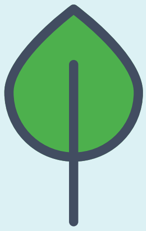
- Relative work intensity using heart rate
- Active vs. resting e.g. time spent awake/asleep
- Relative mobility and activity pattern e.g. distances travelled from the home, off-farm activity, regularity of visits to the paddy field or other places

Activity studies of this nature are becoming more commonplace in developed countries such as Australia, enabled by the widespread use of wearable sensors and good mobile phone coverage etc.

2. AIMS OF THE RESEARCH

This study aimed to examine the feasibility of using activity wearables and smartphones to quantify relative workloads and activity patterns of women and men rural farmers in Indonesia. Specifically:

Test the acceptability and adherence of participants using Garmin wearables and smartphones daily over a period of 5-months.



Develop and implement a protocol for data collection e.g. to monitor workload and activity patterns throughout the agricultural cycle e.g. planting, harvesting.

Develop and test data analytics and to compare with existing methodologies.

3. PROJECT DESIGN

The project was designed in the phases outlined below;

1. **Project design and preparation:** Collaborative workshops between AIP-R, the University of Canberra, Palladium and Omni Design were conducted to co-design the methodology, modify/translate relevant apps, develop surveys and protocols etc.
2. **Rapid Literature Review:** was undertaken to examine other studies that may have used similar objective measures.
3. **Pre-feasibility study:** A small study with members of the research team in the Bojonegoro area of Indonesia (East Java) was used to define technical requirements based on user personas and to pre-test the functionality of the technology.
4. **Socialization of project and recruitment:** A culturally and socially acceptable selection process was developed and the project fully socialised and explained to communities and their representatives. 30 active smallholder households (50% male/female) in one AIP-R intervention location; a total of 60 participants were initially recruited at the start of the programme.
5. **Data collection and analysis:** Data was collected continuously during a full farming cycle i.e. land preparation, seeding, harvesting and drying (over 5 months).

3.1 LITERATURE REVIEW (RAPID REVIEW)

Rapid reviews are typically useful for informing emergent decisions faced by decision-makers and stakeholders (Haby *et al*., 2016, Khangura *et al*., 2012, Tricco *et al*., 2015). The review aimed to summarise the literature on gender differences in occupational workloads in men and women rural farmers and to document the various methods of monitoring and measuring occupational workloads and the roles of women and men.

The rapid review included the following steps:

1. Design and conceptual clarification of the rapid review
2. Purposeful evidence-based searching, and gathering of evidence from electronic databases and by searching for case studies
3. A critical appraisal of existing published research which is 'time-limited' (for relevance)
4. Validation and discussion among the research team
5. Evidence and synthesis report

Key findings from the rapid review:

Electronic databases and the grey literature were reviewed. A total of 68 studies that met the inclusion criteria were analysed; 16 systematic reviews, 8 cross-sectional studies, 20 descriptive/qualitative studies, 17 intervention studies and 7 published reports.

Gender differences are common in rural areas and especially in developing countries. Women are often more disadvantaged than men due to their relatively lower levels of education, lower access to and control over economic and financial resources, lower agency. Most importantly, in comparison with men, women bear with a triple work burden in the productive, reproductive and social spheres. Most of the studies identified used qualitative, descriptive methods to examine gender differences in occupational workload and physical activity patterns. Very few studies used objective measures to examine the workload or division of labour (Table 1) and none were found using smartphones and activity wearables.

TABLE 1 Studies using objective measures of workload: a rapid review

Author	Subjects	Indicators	Assessment methods	Findings
(Singh *et al.*, 2014)	20 Indian women wheat farmers	Heart rate, energy expenditure, cardiac cost of worker	Heart rate monitors, stopwatch	Usage of improved sickles during wheat harvesting activities can increase efficiency, reduce drudgery, avoid posture discomforts and empower women farmers
(Borah, 2015)	40 Indian women farmers	Heart rate, energy expenditure, total cardiac cost of work, physiological cost of work	Polar heart rate monitor, skinfold callipers, direct observation method	Physiological workload, perceived exertion, musculoskeletal disorders and cardiovascular stress are increased significantly among women farmers during firewood collection activities
(Borah and Kalita, 2016)	30 Indian women paddy farmers	Physical fitness, Rating of Perceived Exertion	Polar Heart Rate Monitor, skinfold callipers, Dual inclinometer	Harvesting paddy grains is considered as moderate to heavy farming activity for women farmers. Workers rotation, adequate rest schedule and personal protective equipment provision increase work performance and productivity
(Groborz and Juliszewski, 2013)	234 Polish farmers: 150 women and 84 men	Heart Rate Reserve index, photography of workday	Direct observation method, time diaries, Polar heart rate monitor	Farmer's workload is reduced using mechanical devices. However, there is no significant difference in the method of work performance among manual and mechanical devices
(Joshi *et al.*, 2015)	50 Indian women finger-millet farmers	Human Physical Drudgery Index: heart rate, blood lactate, energy expenditure, posture	Heart rate monitors, physical activity questionnaires, direct observations	Human Physical Drudgery Index of finger millet threshing activity is reduced significantly when millet thresher machine was used, compared to traditional method. Thresher machine is ergonomically feasible and reduces cardiovascular stress and fatigue among women farmers
(Kim *et al.*, 2015)	72 Korean farmers: males 23, females 49	Total Energy Expenditure, Physical Activity Level	24 hours' time diary, Ventilated hood system, Bioelectrical impedance analyser	There is a significant difference in PAL and TEE of farmers between farming and off-farming seasons. TEE of female farmers was higher in the farming season, whereas no difference between the two seasons among males
(Sharma *et al.*, 2017)	30 Indian women wheat farmers	Physiological cost of work, Overall discomfort score	Questionnaires, heart rate monitors	Perceived exertion, drudgery and labour cost of women wheat farmers are reduced by using farming equipment like improved sickles
(Singh and Vinay, 2014)	30 Indian women paddy farmers	Physiological cost of work, a rating of perceived exertion, user satisfaction	Polar heart rate monitor, Questionnaires, direct observation	Drudgery, labour time, postural discomfort and energy expenditure of women farmers during farming activities are reduced by using various paddy thresher machines
(Singh, 2015)	Indian women maize farmers	Heart rate, aerobic capacity	Polar heart rate monitor, direct observation method	The physiological workloads of women are increased significantly in maize harvesting, dehusking and shelling activities. Introduction of farming equipment can reduce drudgery such as maize de-husker-shellers
(Singh, 2016)	296 Indian women	Heart rate, oxygen consumption rate	Heart rate monitors	The physiological workload of women varied for same farming activity in the similar environment due to their capacity and heart rate variability

3.2 PRE-FEASIBILITY STUDY

3.2.1 Location

The study location was selected in Besah village of DSN Palangan hamlet, Bojonegoro district, Indonesia (Figure 1). It is located in East Java region and about 110km west of Surabaya region. Most of the residents in the village are paddy farmers and they receive water from the nearby river — Bengawan Solo river. They cultivate peanuts, soybeans and maize when they don't have adequate irrigation from the river or access to water. Most of the residents speak Javanese/ Bahasa languages, and they practice Islam and Christianity as main religions. This village was selected as the sample location for the study due to its homogenous irrigated farming lands.

3.2.2 Validation of technical functionality

The pre-feasibility study was conducted in Bojonegoro district, East Java province, Indonesia. Field workers and enumerators from the TIRTA project installed the 'Moves' and 'Google Fit' app and wore the Garmin wearable trackers for a duration of 2 weeks. The electronic devices were tested for performance and potential network connectivity issues.

3.3 PARTICIPANTS SELECTION

3.3.1 Socialisation and recruitment

30 farming households in Besah village, already registered in the TIRTA database (60 individuals including 30 men and 30 women) were selected for the study. Since this was a feasibility study, a formal sample size calculation formula was not utilised.

Inclusion criteria included;

- Paddy farmers who live and work in Besah village of Bojonegoro region, Indonesia
- Famers who are registered in TIRTA database
- Over the age of 18
- Willing to wear the Garmin wearable and carry the smartphone with them daily over the agricultural cycle

Local field workers initially approached eligible participants to assess eligibility, interest and ability to commit to participating in the study. Using the selected technology for data collection requires signing up to the service with a personal email address. To protect the participants' privacy ID numbers and pseudonym email addresses were created. Each account only used the study identification number (P001, P002, etc) and did not include the participants' name, age, or any other personal information. A team of project workers then visited the selected farming households (Figure 2).

FIGURE 1 Location of the study area — Bojonegoro district, Indonesia

FIGURE 2 Participant enrolment process

Ethical approval was obtained from the ethical review committee of the University of Canberra.

The objectives of the study were explained clearly to each participant. Study information sheets (see Supplementary Information) were provided to participants and all gave their verbal and written consent. After consent, the participants were provided with a 'Garmin Vivo smart 3' wearable activity tracker (worn on the wrist), a 'Samsung Galaxy J2 Prime' smartphone with a mobile pre-paid SIM card. Three apps were installed on the smartphone: 'Garmin Connect' app (retrieves activity data from the 'Garmin Vivo smart 3'), 'Moves' app and 'Google Fit' were used to collect GPS location of the participant. The Garmin, Moves and Google accounts were set up using ID email addresses. For the Garmin account, height and weight were added so that this could be used by the app' to estimate energy expenditure and stride length. The functions of electronic devices were demonstrated to all participants. The language of the devices was set to Bahasa (Indonesian) for their convenience.

After setting up the devices and mobile apps, field workers were granted access to participants' IDs through a project research console designed by Onmi. This console had two functions: 'Link devices' provides access to a participant ID, 'Dashboard' provided a traffic light system that allowed the researchers to monitor the incoming data per participant and to alert if the device was not being worn. Figure 3 shows the console for monitoring of incoming and missing data. Green indicating data was uploaded within the last 2 days, yellow indicates between 2 and 5 days, and red denotes more than 5 days since data was uploaded. Researchers were able to notify field workers in the area to contact participants if their data was not being uploaded or wearables not being used regularly.

Participants were asked to wear their Garmin tracker all the time including performing farming activities and sleeping. They were also asked to carry their mobile phones at all times (especially when working in the paddy fields).

Each week the Console was checked for compliance and identified participants who had not used the devices or if there were issues with the devices. If data were missing, the field worker visited the participant to deal with any technical issues. The most common reason for missing data were participants running out of mobile data and misunderstanding of the smartphone settings or the pairing process.

On return of the electronic devices, each participant was given the equivalent of AUD$30 in cash. Three participants dropped out of the study: one participant dropped their smartphone into the water, one participant broke their Garmin device and the other participant had data synchronisation issues.

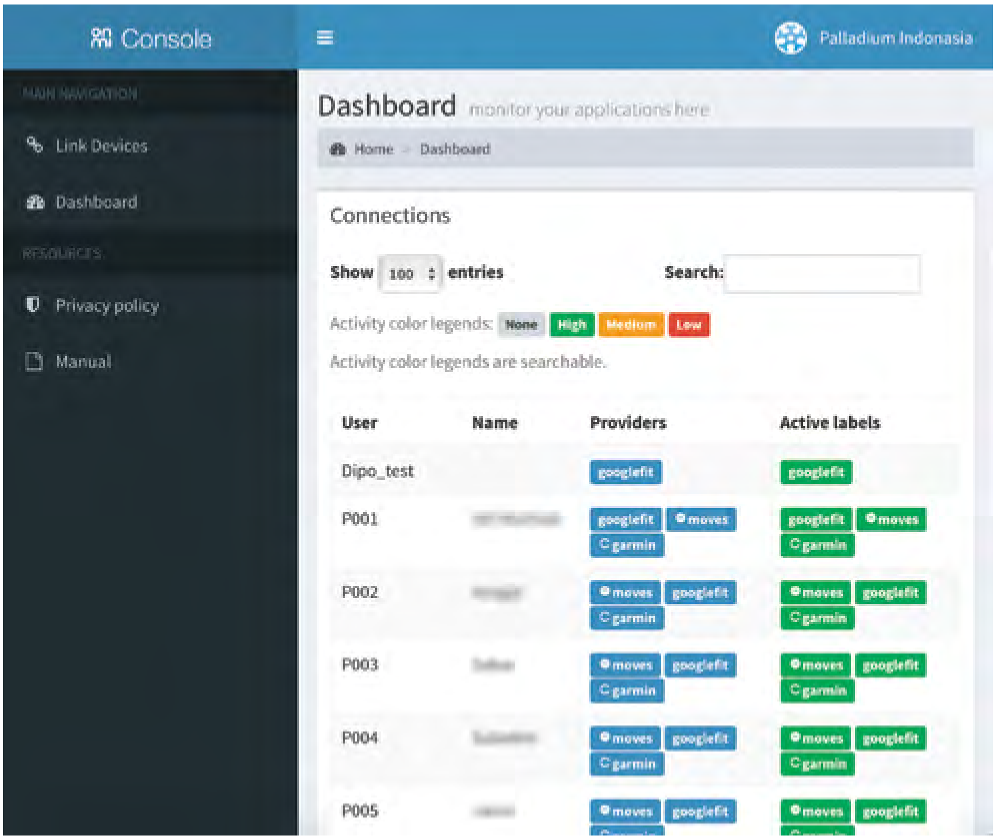


FIGURE 3 IT console for monitoring of incoming and missing data

3.3.2 Field observations

The following observations were made during the field visits;

- Motorbikes and bicycles were the standard modes of transport along with walking. Most roads in the villages were poorly maintained.
- Smoking was prevalent across most of the male participants, some male farmers smoked heavily.
- There was a significant difference evident between the economic status of some paddy farmers in the study, even among the neighbouring households; for example, some homes were furnished with tiles, whereas other homes had only clay roofs and uneven floors.
- Standard features of housing structures: walls were made with cement, and wooden strips and most of the houses had a veranda/front yard.
- Most of the participants had started their land preparation and planting process at the time of the recruitment. Figure 4 illustrates some of the main farming activities.
- Children were more familiar with using a smartphone and 'tech-savvy' than their parents and they helped their parents with the settings of the smartphones and wearables. However, some children were found to use the smartphones themselves to connect to the internet.
- Most participants did not own a smartphone. Their adoption of modern technology was low in general: i.e. not every household had a television; kitchen work and washing of clothes were done manually.
- Some participants expressed a clear preference in the colour of their smartphone and Garmin device. Allowing them to make a personal choice helped increase their engagement with the project.
- Most of the participants did not know their own height or weight, and one did not know their date of birth.
- The participants daily behaviour was determined by daylight: they woke up with sunrise and went to sleep quite soon after dark. Households did use lights in the evening, but there was not much artificial light in the village, only an occasional streetlight.

FIGURE 4 Farmers working in the paddy fields (with Garmin devices)

3.4 DATA COLLECTION

Two services were used 'Consume and Collect', to facilitate the data acquisition and aggregation from the external third-party sources Garmin, Moves, and Google Fit.

The Consume service facilitates the authentication and authorisation of the participants granting Onmi access to the data through a web browser view. The Collect service requested data from the external, third-party APIs through the Consume service, with Consume, only authenticating requests made by the Collect service. The primary reason to separate these services was to allow hosting on different servers, thereby ensuring security. The participant's identity was pseudonymised by an identity provider service e.g. indicated by 'Auth0'.

3.4.1 Personal data

Basic demographic data was collected verbally and recorded e.g. age, gender, identification number, allocated mobile number, type of farming activities involved, and income details were obtained from each participant.

3.4.2 Activity data

Garmin 'Vivo Smart 3' and smartphone's 'Moves' and 'Google Fit' automatically recorded the following data: walking distance, steps count, heart rate per minute, GPS location of participants, distance travelled in a day, stress level, dates, body mass index, total calories and activity intensity levels. Specification of Garmin wearable and relevant information can be requested in the Supplementary Information material. Work rate, workload or 'intensity' of physical activity of farmers were classified into three categories based on heart rate (HR):

1. Light work (HR: < 90)
2. Moderate work (HR: 90–110)
3. Heavy/vigorous work (HR: > 110)

3.5 DATA PROCESSING

Python 2.7 software was used for the geo-analysis. GPS traces were provided by GoogleFit from the database and transformed to a data frame format. The data frame included longitude, latitude, time and date and other matrixes provided by GoogleFit. For every participant, the location traces were sorted by time and a density-based spatial clustering analysis performed. DBSCAN is the data-clustering algorithm, which was used to find the cluster locations within a 20-meter radius (Ester *et al.*, 1996). The primary reason for using DBSCAN is that it can discover arbitrary patterns without specifying the number of clusters, unlike the k-means method (Ester *et al.*, 1996). DBSCAN has a notion of noise and is robust to outliers.

The clustering yields a set of labels that identify the member points to a cluster. These points are merged using the temporal dimension to find the start and end times for each visit to the given cluster. The centroid for each cluster is matched to the known locations for the participant, helping to tag the locations as 'home', 'farm' or 'other'. Additional steps are performed to enrich the places by extracting activity data from Garmin for every visit. The enrichment dataset included activity epochs, stress-details, and heart-rates values.

Using the enriched dataset, the values were aggregated: 'steps', 'met', 'durationInMin', 'meanHR', 'meanStressLevel' and 'meanMotionIntensity'.

3.6 DATA ANALYSIS

After one month of data collection, preliminary data analysis was conducted to verify the collected data and findings were compared with the results of the pre-feasibility study. Descriptive statistics were calculated using the Statistical Package for the Social Sciences (SPSS version 25) and Microsoft Excel package 2017 (IBM, 2017). For the final study analysis, statistical tests such as T-test, One-way ANOVA and two-way ANOVA test were conducted to examine statistical differences of study variables between men and women, within the different locations and various farming stages of the agricultural cycle.

4. RESULTS

4.1 SAMPLE PERSONAS

In preparation for the study, all technical requirements were defined for the selection of appropriate wearables by creating personas of 'typical' Indonesian farmers in the Bojonegoro district. The personas are based on previous work in the TIRTA project. Including FGDs and surveys looking at gender labour division and workloads.

Case study

Sample persona 1 — Male 1

Name	Male 1
Demographics	Male 1, 52 years old, married to a 47-year-old woman, one married-son living in Surabaya, one daughter living in the house (17 years old), one son living in the house (15 years old), primary education
Occupational profile	Paddy farmer and construction worker
Farming activities	Land preparation, ploughing, sowing seed, weeding, spraying pesticides, fertilizer application, scaring birds and rats, harvesting, rearing cattle
Farming skill set	Hand tractor, knapsack sprayer, weeding tools, paddy thrasher machine
House amenities	Flooring: cement plastered; wall material: brick; water source: tap water; toilet: available in the house; electricity: 900 watt

Male 1 is a Javanese paddy farmer and has been a farmer all his life. He owns a small plot of land (around 0.4 hectares), which is located 2km from his house. He is married and has three children, two of which are still in school and live with them, while their elder son lives in Surabaya (capital of East Java 142km away).

Their land is flooded throughout the rainy season but they have access to irrigation so they only grow paddy from May to November (twice). In the first months of the year, he works as a construction worker across various sites within the District of Bojonegoro, while his wife tends the cattle and works as planting labour with other women farmers from her village in the surrounding areas that are not flooded.

In the dry seasons he and his wife both cultivate paddy; on average they can spend 4 to 7 hours in the field per day depending on the cultivation stage — planting and harvesting time being the busiest of the year. Besides working in the field, the wife takes care of all house chores.

The wife is even busier in May and September which are the peak planting months whereas the husband is busier in July and November. When the paddy is harvested, the wife often has to wake up earlier than usual and prepare and deliver two meals a day and snacks for the labourers they have hired.

Male 1 is one of the wealthiest farmers in the village. He bought a small tractor which he uses to plough his own land and the land of other farmers, so he spends relatively more time in the field in April and August.

Case study

Sample persona 2 — Female 2

Name	Female 2
Demographics	Female, 38 years old, married to 43 year old man, one daughter (16 years old) and two sons (13 and 6 years old), primary education
Occupational profile	Paddy farmer and housewife
Farming activities	Planting, weeding, spraying pesticides, scaring birds, cooking for laborer
Farming skill set	Knapsack sprayer
House amenities	Flooring: soil; wall material: half brick-wooden; water source: groundwater; toilet: available in the house; electricity: 450 watt

Female 2 is a 38 years old Javanese farmer. She inherited a small plot of land from her father (around 3.5 Ha) which she cultivates with her husband, who is 43 years old. They have three children who live with them and are still in school — the eldest is 16 and the youngest is six.

The paddy field is located 1km from their house in a hilly part of Bojonegoro and far away from the river where irrigation is not available. This means that have to start growing paddy early in the rainy season (December) and often have to take the risk to plant paddy again as soon as they harvest, around April.

During this time they work in their field for around four to seven hours a day. She is busier during the planting season when she works also as paid labour, whereas her husband is busier in March when her husband often goes as far as Ngawi and Cepu (two districts close to Bojonegoro) to work as a harvest labourer for around two weeks while she takes care of their land.

In the second dry season, from around August, they start cultivating soybean — soybean is relatively less time intensive than paddy. As they do not have to go to the field as much as when they grow paddy, her husband works as paid labour where irrigation is available and farmers grow paddy even in the second dry season. The woman cannot join the planting groups in the East of Bojonegoro as it is too far and someone needs to be at home with the children while her husband is away.

4.2 PRELIMINARY DATA ANALYSIS

Data collection was ongoing from May 2018 to October 2018. A preliminary data analysis was done in June 2018. This descriptive analysis focussed on data completeness and comparing average sleep/ activity of men and women on weekdays versus weekends.

First, the data completeness was calculated. The available days of sleep data were compared to the total amount of days since the participants started the study. For the first sleep analysis, the completeness of data was 74%. For interpreting sleep behaviour, the 'durationInSeconds: length of the monitoring period in seconds' data from the Garmin API was used. From the available sleep data, average sleep duration during weekdays (Monday until Friday) and weekend (Saturday and Sunday) were calculated. Based on Figure 5, men on average slept 6 hours 19 minutes during weekdays and 6 hours 12 minutes on weekend. For women, this was 6 hours and 42 minutes and 6 hours and 43 minutes respectively.

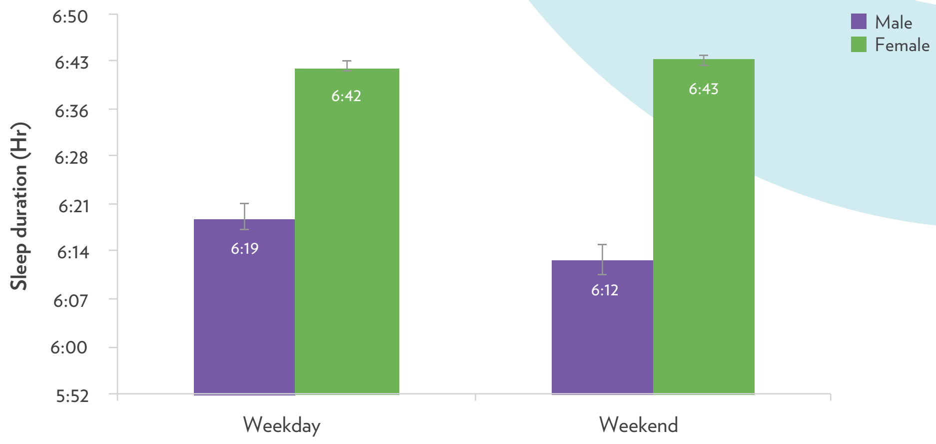


FIGURE 5 Average sleeping hours of men and women (Standard error bars are shown)

For activity, the data completeness was calculated by comparing the total amount of days with steps data (requirement that steps> 0) to the total amount of days since the participants' inclusion in the study. For this first analysis, the data completeness was 91%, of the total 1,371 measurable days since inclusion, 1,246 were recorded. For interpreting physical activity, the 'steps: Count of steps recorded during the monitoring period' and 'distanceInMeters: distance travelled in meters' from Garmin API were used. For men, the average steps on a weekday were 11,339 (8.5km) and during the weekend 11,602 (8.7km). For women, this was 8,329 (5.8km) on a weekday and 8,682 (6.0km) on the weekend (Figure 6). The preliminary data analysis did not show any significant statistical difference between weekdays and weekends. Therefore the data was not partitioned for weekends in the final analysis.

FIGURE 6 Average steps of men and women (Standard error bars are shown)

4.3 STUDY RESULTS

The average age of the participant was 49 years (±8). The average age of men was 51 and the average age of women was 46 years.

4.3.1 Farming stages

The participants began their farming cycle for the dry season 1 from April to August 2018. The different stages of dry season 1 included: the preparation stage, vegetative stage, harvest stage and post-harvest stage (Figure 7).

During the preparation stage, farmers have prepared their lands for seeding using hand-tractor and farming tools (Figure 8). Typically, one farmer was required for the half-day sowing of 40kg seeds per one hectare of land and, 12 farmers were required for half-day seeding of paddy grains per 0.5 hectares of land. Most of the farmers received water from the irrigation scheme of TIRTA.

The vegetative stage consisted of application of fertilizers, pesticides and weeding. On average, farmers applied 3 intermittent applications of fertilizers and 6–10 intermittent application of pesticides for one season (Figure 9). Scaring birds was done towards the later stages when the paddy had set seed.

The harvesting stage was completed from July to August. Typically, 0.5 hectares of paddy field required one day of harvesting. During the post-harvest stage, some farmers dried the paddy grains for their personal consumption (Figure 10).

The detailed farming calendar of paddy crops in Besah village is included in the Supplementary Information. However, some of the farming stages overlapped during the dry season 1 and some stages were inconsistent among few participants. Therefore, four comprehensive farming stages were developed for data analysis as described in Figure 7.

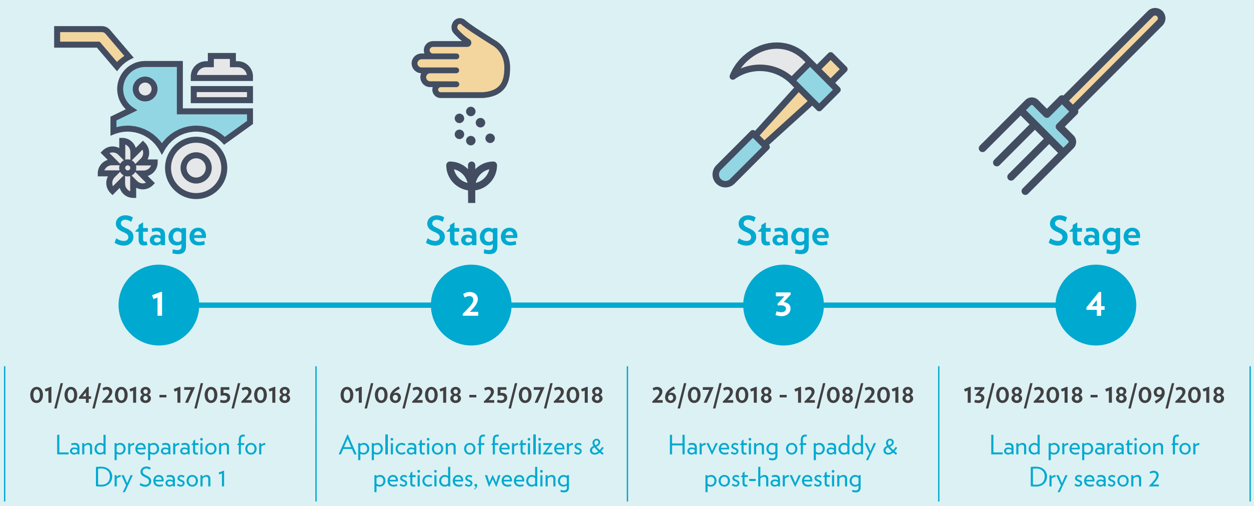


FIGURE 7 Timeline of farming stages

FIGURE 8 Land predation stage: sowing, seeding & irrigation (Stage 1)

FIGURE 9 Vegetative stage: applying fertilizers and pesticides (Stage 2)

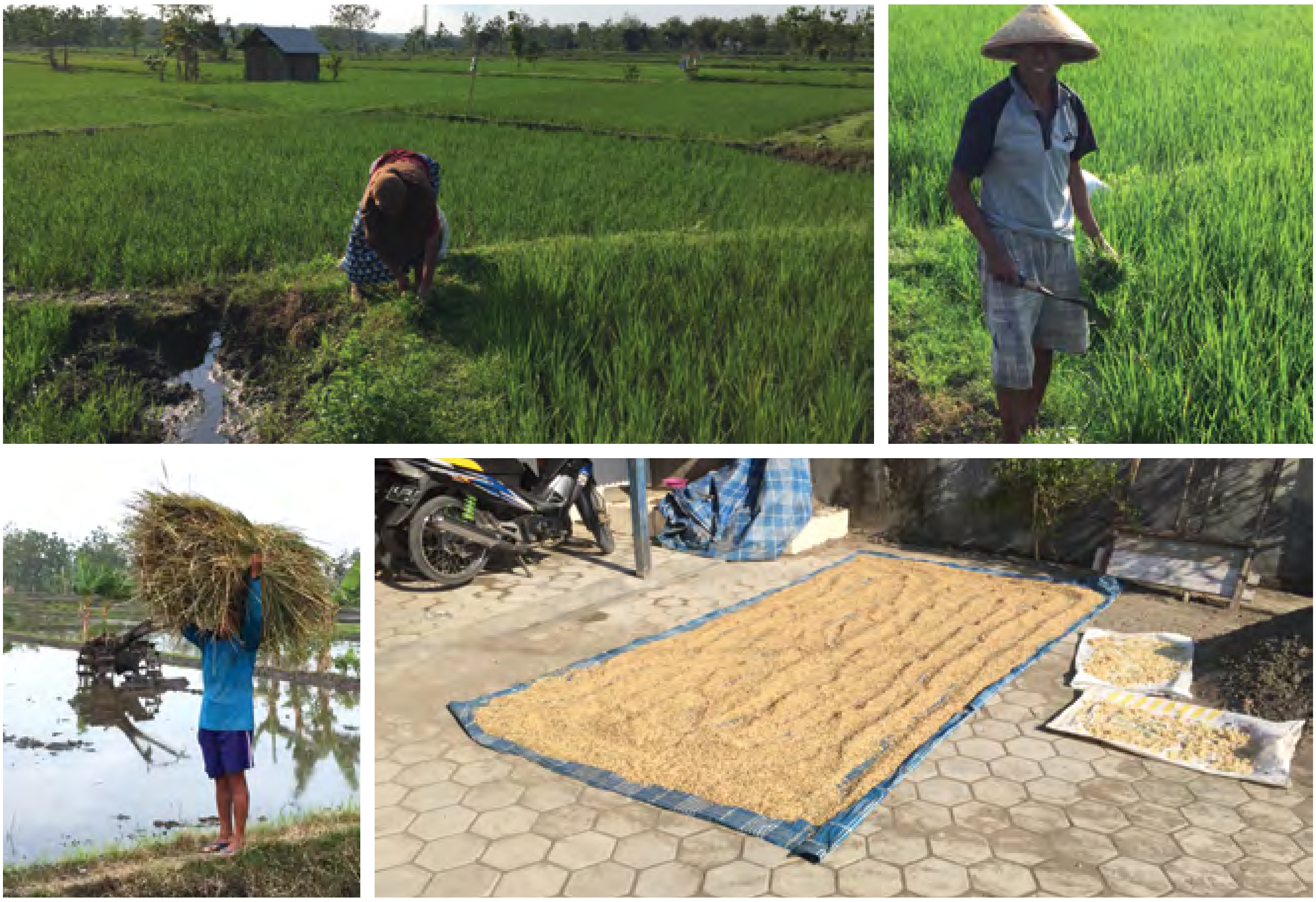


FIGURE 10 Harvesting of paddy grains & post-harvesting sun-drying (Stage 3)

4.3.2 Data completeness

All data were checked for completeness. The purpose for this was to establish the quality of the dataset and missing data. For each data indicator this analysis is different, but generally, the aim is to evaluate the percentage of data from the total inclusion wearable time available. Data collection for participants was started from 8th May 2018 continuously over a 5-month period. Three participants (P011, P013 and P031) were excluded from the study due to technical problems. P011 participant broke their Garmin, P031 participant broke their smartphone and P031 participant had synchronisation problems that could not be solved. However, overall compliance was very high, and most participants found the use of the wearable and smartphone acceptable.

Heart Rate (HR)

Garmin API returns HR data in 15 seconds intervals for each calendar date, regardless of whether any data is collected. This means for each day we have 5,760 possible values, if the Garmin is not worn (correctly), the time interval has no HR value. For completeness, we compare the available HR values to the total 5,760 possible values. From 60 participants, 57 participants had above 60% of HR completeness.

Steps and distance walked

Garmin API returns values for each calendar date regardless of whether any data was recorded. This can result in a day with 0 'steps' or 0 'distanceInMeters' if the Garmin wearable was not worn. For analysis, the total amount of days the participant was included is counted and compared to the number of days where the 'steps' and 'distanceInMeters' were not 0.

For Garmin steps and distance covered a total of 6996 out of 7513 days have been recorded. This means a data completeness of 93%. This is comparable to other studies measuring physical activity levels. Studies using activity monitors such as accelerometers, usually only report 7 day periods of wear time but find wear time, on average, for nearly 80% of the monitoring period (Wickel, 2014).

Sleep

Garmin API only returns calendar days when sleep duration was recorded. For analysis, the total amount of days is counted where the participant recorded data and compared to the total number of calendar days available. To be safe, any days where 'durationInSeconds' was 0 are excluded.

For Garmin sleep, a total of 5,546 out of 7,513 days have been recorded. This means a data completeness of 74%.

4.3.3 Location-based analysis

The analysis of Google Fit GPS data revealed 'hotspots' or locations/places that are frequently visited by the participant. Each hotspot is identified and numbered so the total number of hotspots, the frequency of visits to a hotspot together with the amount of time spent at a hotspot can be calculated. Locations are categorised into 'home', 'paddy field' and 'other' e.g. mosque, friend's house, local amenities etc.

Local enumerators visited each participant's household and asked them to locate on a map the location of their homes and paddy field. Figure 11 shows the overview of all identified rice paddies (border of a farm paddy outlined in red) in Google Earth. The rice paddies and home of couple P006 / P001 are highlighted as an example. We can see this couple has 6 paddy fields, and their home is on the edge of the village. The number of paddies per household ranged from 1 to 7.

Once the relevant hotspots for 'home' and 'paddy' were identified, GPS was used to map mobility patterns in men and women. We monitored the frequency of visits to the paddy fields, from/to home and to 'other' destinations (Figure 12) for men and women over the 5-month period. A number of the visit was recorded in the Garmin device as the number of times a participant had arrived at the specific location.

Men have a higher frequency of visits in all three categories (home, farm and other). Men travel around more and between places than women. Men and women have similar behaviour in the different stages; they visited the farm the most in preparation stage 1, the second most during harvesting, and the least during the vegetative stage. Men visited about 5–6 'other' places each day. Women visited about 2–3 'other' places each day. Throughout all farming stages, the men visit the farm more than women. Both men and women visited the farm less in preparation stage 2 than in preparation stage 1.

Gender and location have a statistically significant effect on average visits of participants to different locations. The average number of visits of men to different locations are statistically higher than women (p-value $0.01 < \alpha$ value 0.05). The mean average number of visits to the farm, home and other locations of men are 23, 45, 110 and women's mean values are 7, 25 and 56 respectively. Among three locations, an average number of visits is significantly different in other locations (mean 83), compared to farm (mean 15) and home (mean 35). However, there is not enough statistical evidence to conclude that gender and different farming stage have significant effects on average visits of participants. The detailed statistical analysis is included in the Supplementary Information.

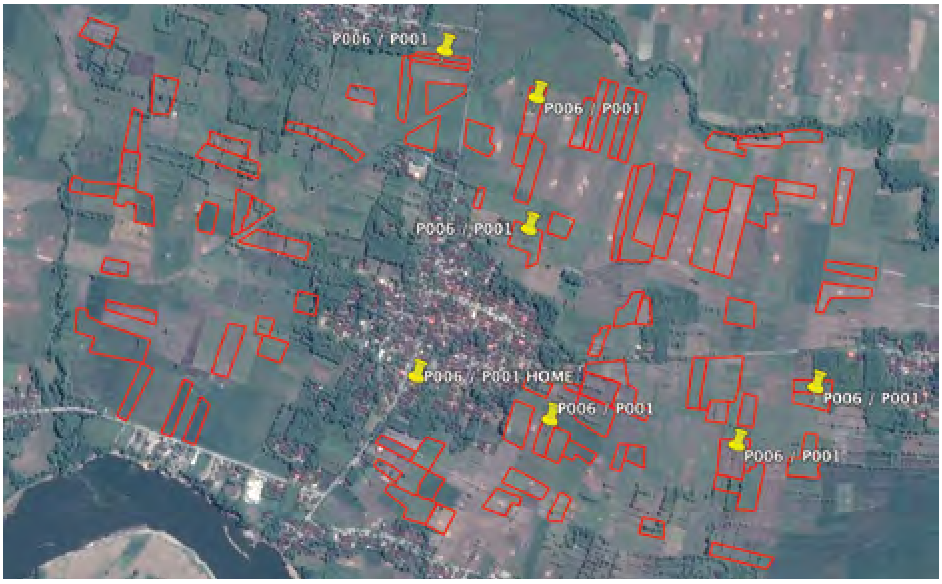


FIGURE 11 Hotspots of frequent locations in Google map

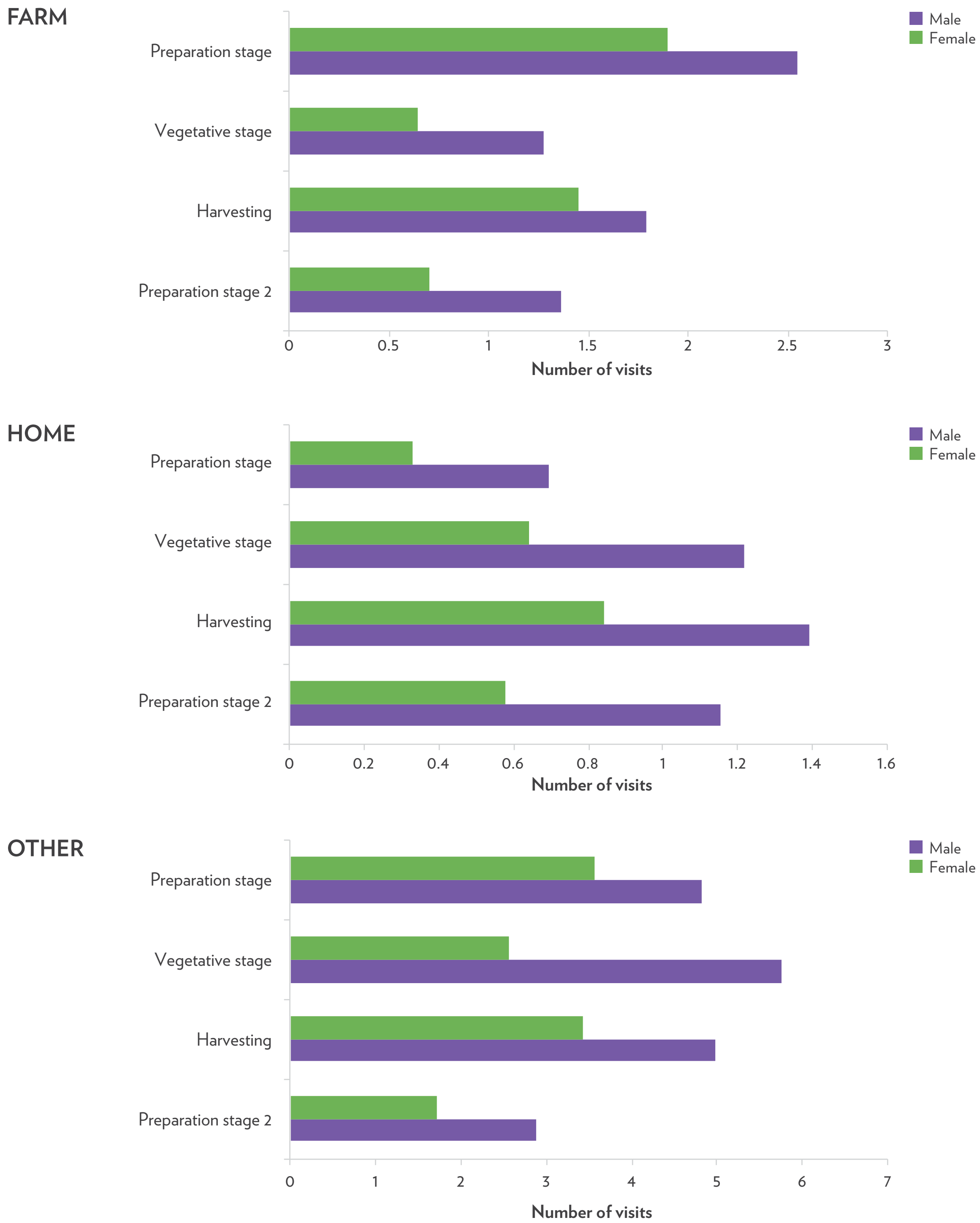


FIGURE 12 Average number of visits per day at each location

Figure 13 shows the average time spent at locations per visit over the 5 month period. These values are determined based on processed Google Fit GPS tracepoints. Gender and location have a statistically significant effect on the average time spent by participants in different locations. The average time spent in the home is statistically higher among women, compared to men (p-value 0.00 < α value 0.05). The mean average time spent in the farm, home and other locations of men are 76, 390, 54 and women's mean values are 78, 552 and 68 respectively. However, there is not enough statistical evidence to conclude that gender and different farming stages have significant effects on the average time spent by participants.

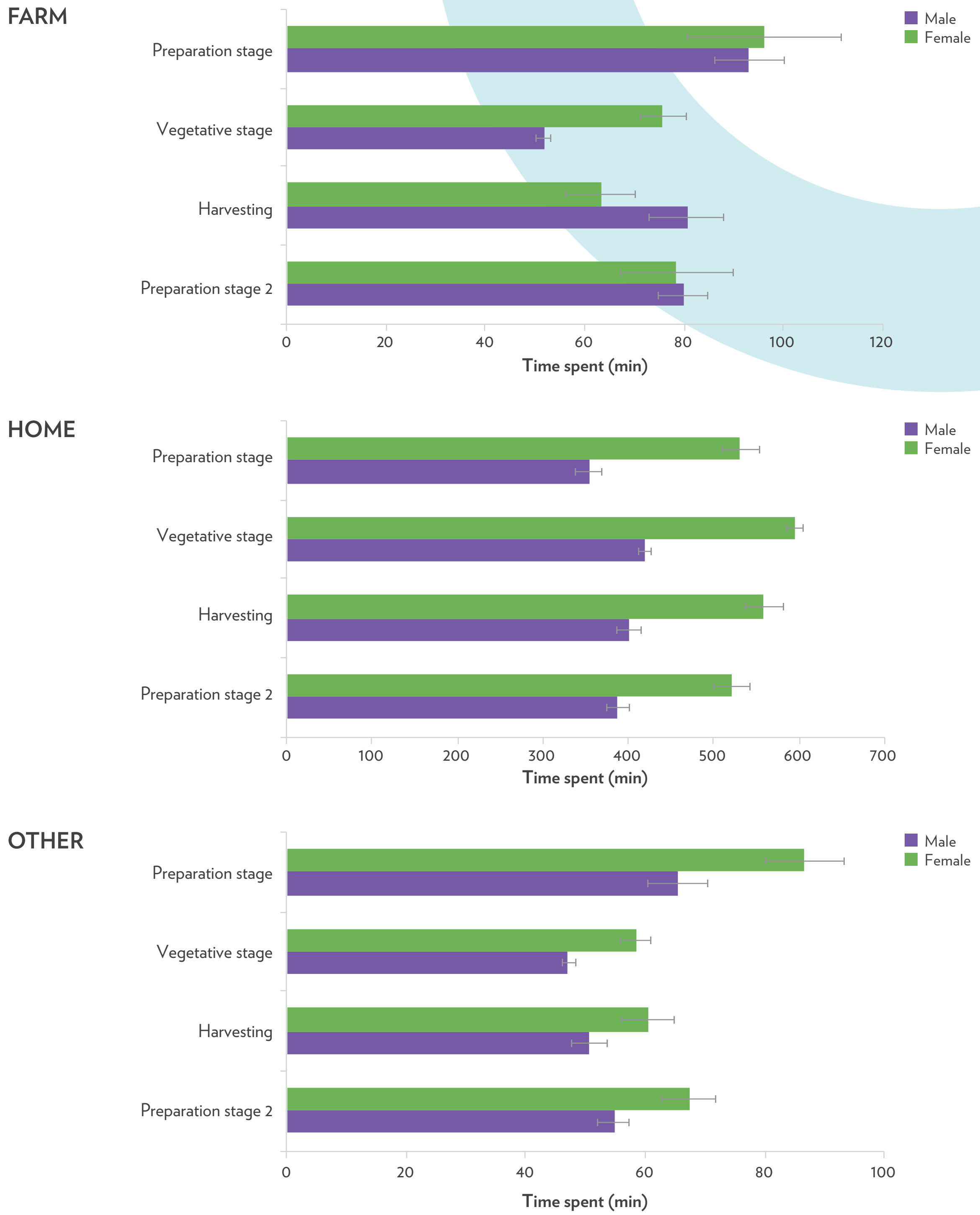


FIGURE 13 Average time spent per visit in each location (Standard error bars are shown)

Women spend more time at home than men, regardless of the stages i.e. Preparation stage 1: 50% more, Vegetative stage: 42% more, Harvesting stage: 40% more. Preparation stage 2: 34% more. Both men and women spend most of their time per visit at home during the vegetative stage. Men and women tend to spend most of their time per visit at the farm during preparation stage 1.

Table 2 shows the estimated average time women spend at each location; so for example,

Stage 1: the woman visits the farm 1.9 times per day, for an average duration of 96 min. This is 182 minutes which is 3 hours per visit.

Stage 2: The woman visits the farm 0.6 times for 76 min, this is only 46 minutes per visit.

Stage 3: The woman visits the farm for 1.5 times for 63 minutes so total time spent is 95 minutes per visit.

Stage 4: The woman visits the farm 0.7 times for 79 minutes, so the total time spent at the farm is 55 minutes per visit.

Step counts are attributed to the different locations by extracting the step counts within the visited time frame as reported by the Garmin Vivosmart 3. Figure 14 shows the average number of steps per visit to each category of location: home, farm, other, (for men vs woman).

Gender and location have a statistically significant effect on average steps of participants to different locations. There is enough evidence to suggest that gender (p-value 0.001< α value 0.05) and location (p-value 0.00< α value 0.05) have a significant effect on the average steps of participants. The mean average steps in the farm, home and other locations of men are 70, 12, 125 and women's mean values are 37, 8 and 88 respectively. However, there is not adequate statistical evidence to conclude that gender and farming stages have significant effects on average steps of participants.

Both men and women accumulate most of their step counts in 'Other' locations. This can be attributed to the fact that 'Other' may include a range of locations e.g. the mosque, shops/amenities, a neighbours paddy field etc. Men make more steps per visit at the farm than women. Overall men have higher step counts per visit to all three locations than women.

TABLE 2 Total time spent on the farm per visit

Stages	Average time spent on the farm (min)		Average number of visits to the farm per day		Total time spent on the farm (min) per visit	
	Men	Women	Men	Women	Men	Women
Preparation stage 1	93	96	2.5	1.9	232	182
Vegetative stage	52	76	1.3	0.6	68	46
Harvesting	81	63	1.8	1.5	146	95
Preparation stage 2	80	79	1.4	0.7	112	55

FIGURE 14 Average number of steps per visit in each location

4.3.4 Activity Radius analysis

The GPS trace-points obtained from Google Fit were used to estimate the average distance participants travelled by any mode of transport (i.e. walking, bicycling, motor vehicle). For every participant, the GPS locations are collected daily. The travel distances from the centre of the village are used to determine a 'travel radius'. These distances were analysed for men and women (Table 3).

The following visualisations are made with help of **www.mapdevelopers.com/draw-circle-tool.php** (Google, 2018). For the centre of Besah village coordinate (7°8'34.60"S 111°38'28.38"E) was used, and the radius was drawn around this.

- 90% FEMALE
- ACTION RADIUS FEMALE
- 90% MALE
- ACTION RADIUS MALE

TABLE 3 Radius travelled by participants from the centre of Besah village

		Travel radius (km)	Travel radius (km)	Travel radius (km)
Stages:	**Role:**	**Mean**	**90 percentile**	**Max**
Preparation stage	Man	3.06	6.14	36.24
	Woman	3.20	5.65	100.45
Vegetative stage	Man	3.73	6.24	162.88
	Woman	5.65	6.96	162.88
Harvesting stage	Man	3.46	5.28	120.58
	Woman	6.97	6.74	122.02
Preparation stage 2	Man	3.13	7.45	64.45
	Woman	2.47	5.22	76.35

Women have a bigger average travel radius than men in the preparation stage 1 and harvesting stage. During the preparation stage, women's average travel radius is 5% bigger than men's. During the vegetative stage, men's average travel radius is 41% bigger than women's radius. During the harvesting stage, women's average travel radius is 67% bigger than men's. During preparation season 2 men's average travel radius is 24% bigger than women's. It may be that women may travel further outside of their village to visit relatives in the preparation and harvesting stages (Figure 15 to Figure 18).

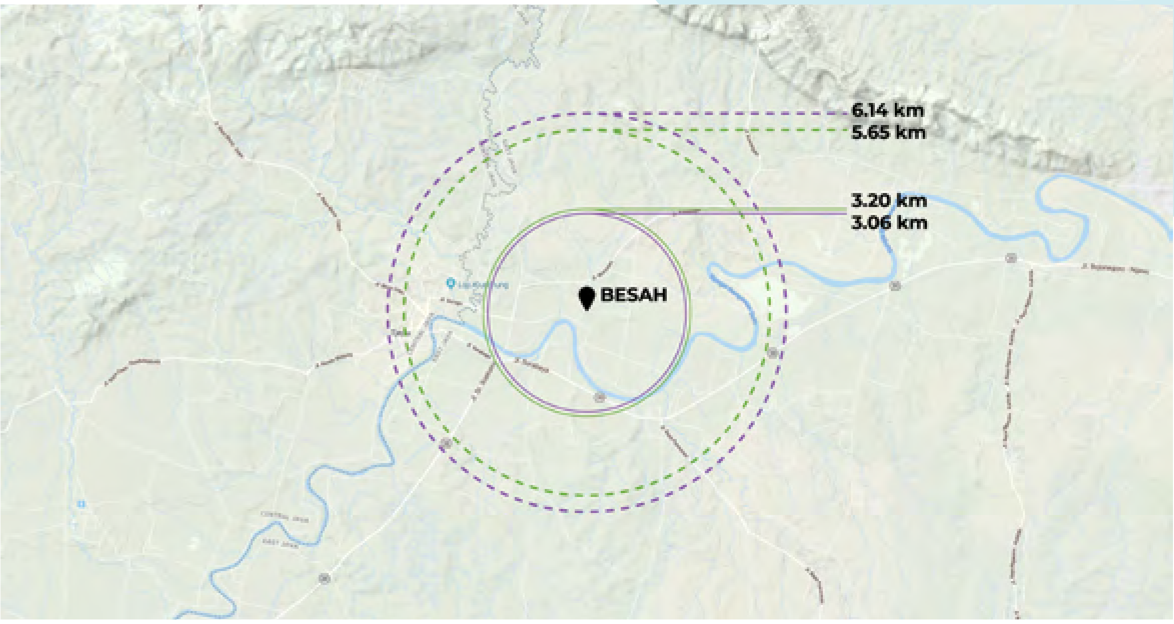


FIGURE 15 The average radius of men and women during preparation stage 1

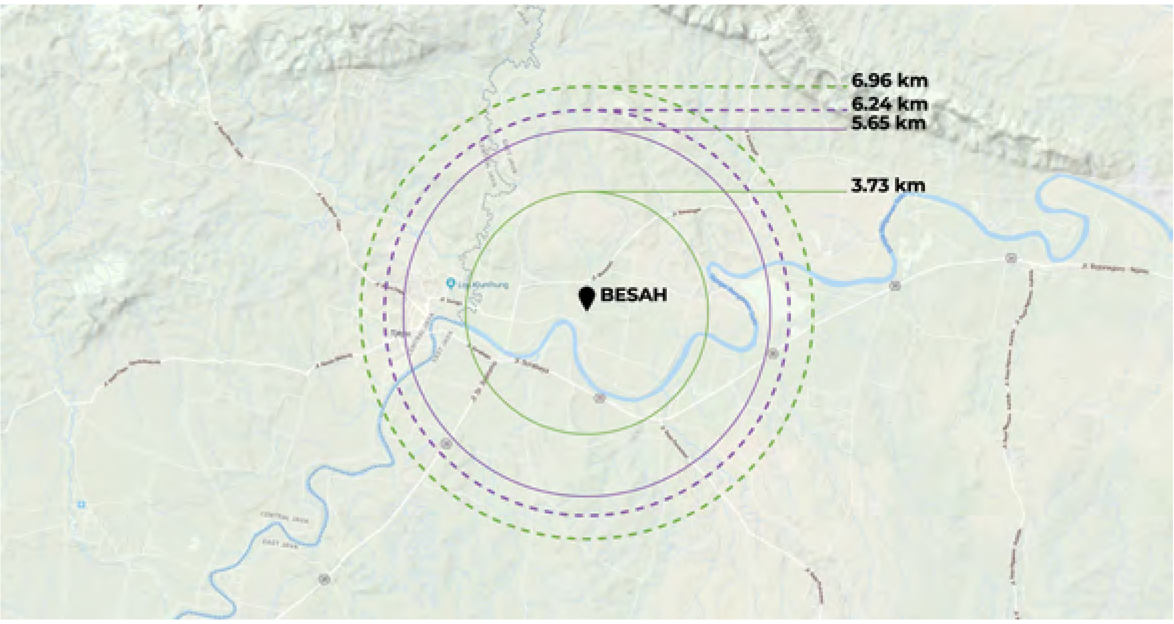


FIGURE 16 The average radius of men and women during the vegetative stage

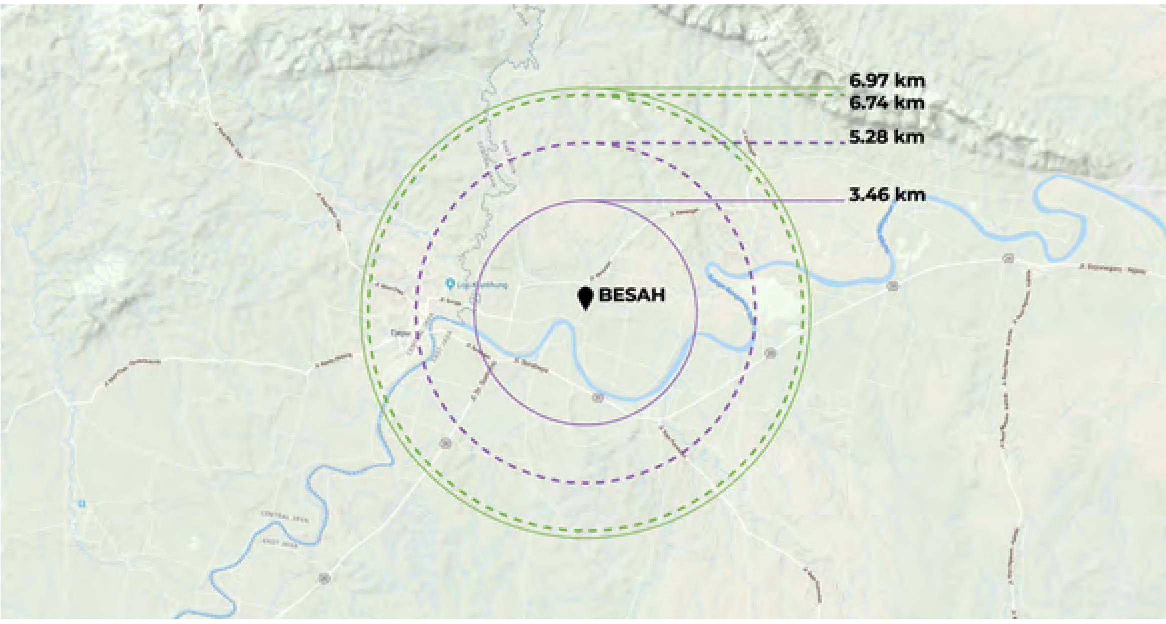


FIGURE 17 The average radius of men and women during harvesting stage

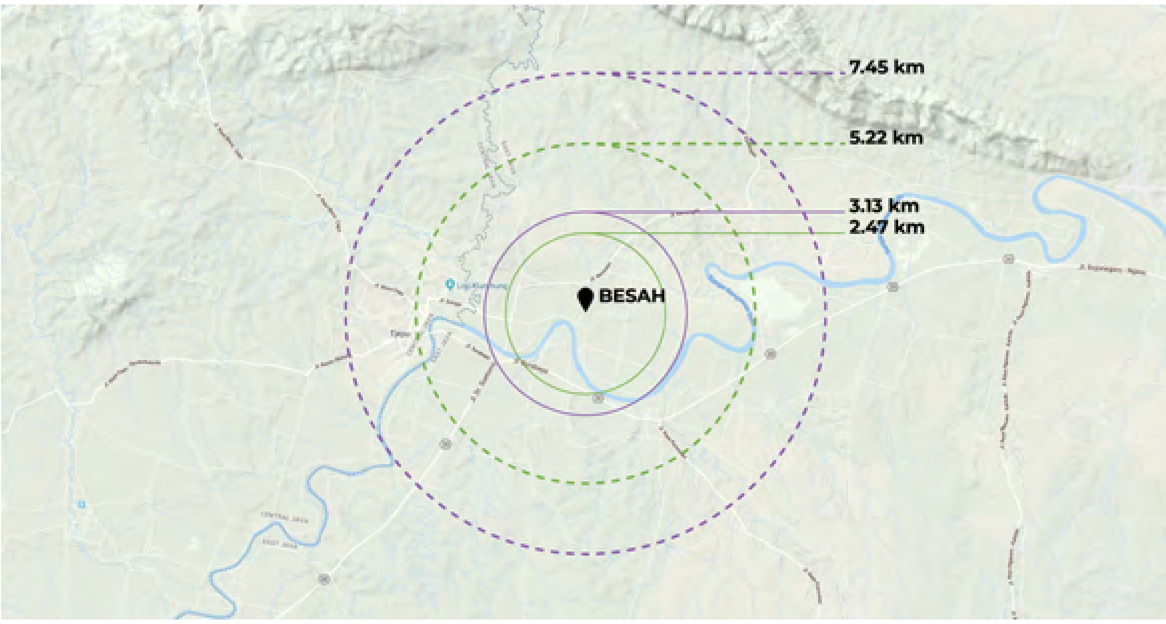


FIGURE 18 The average radius of men and women during preparation stage 2

Figure 19 provides additional insight into the travel behaviour of the study participants. Men make more frequent trips than women, but often do not travel further than approx 26km. This could be to the nearby town Bojonegoro. Men and women also travel together when making a longer trip e.g. 95km travel radius. Women also make trips by themselves and appear to travel further get to these destinations compared to men.

4.3.5 Workload analysis

The following variables are extracted from the Garmin devices for workload analysis:

- 'averageHeartRateInBeatsPerMinute': Average of heart rate values captured during the last 7 days, in beats per minute. The average heart rate value for the monitoring period can be calculated based on the data from 'timeOffsetHeartRateSamples'
- 'maxHeartRateInBeatsPerMinute': Maximum of heart rate values captured during the monitoring period, in beats per minute
- 'restingHeartRateInBeatsPerMinute': Average heart rate at rest during the monitoring period, in beats per minute
- 'timeOffsetHeartRateSamples': List of mappings between offset from start time (in seconds) to a heart rate value recorded for that time, in beats per minute. Especially, heart rates are recorded for every 15 seconds during the monitoring period

Establishing differences in workload in the paddy field (using heart rate) and at home requires attributing the data parameters and heart rate to specific locations. From Figure 20, it can be seen that women consistently have average higher heart rates around the home than men. This is probably because women undertake most of the domestic duties and men mostly rest when they are at home.

Based on statistical analysis, average heart rate (AvgHR) is affected significantly by the location (p-value 0.00); So there is a statistically significant difference among the AvgHR of a participant between home, compared to farm and other locations. The mean average heart rate of a participant in the farm, home and other locations of men are 93, 82, 91 and women's mean HR values are 91, 85 and 89 respectively. However, there is no statistical difference in average HR between men and women (P-value 0.812 > α value 0.05) and between different farming stages (P-value 0.091).

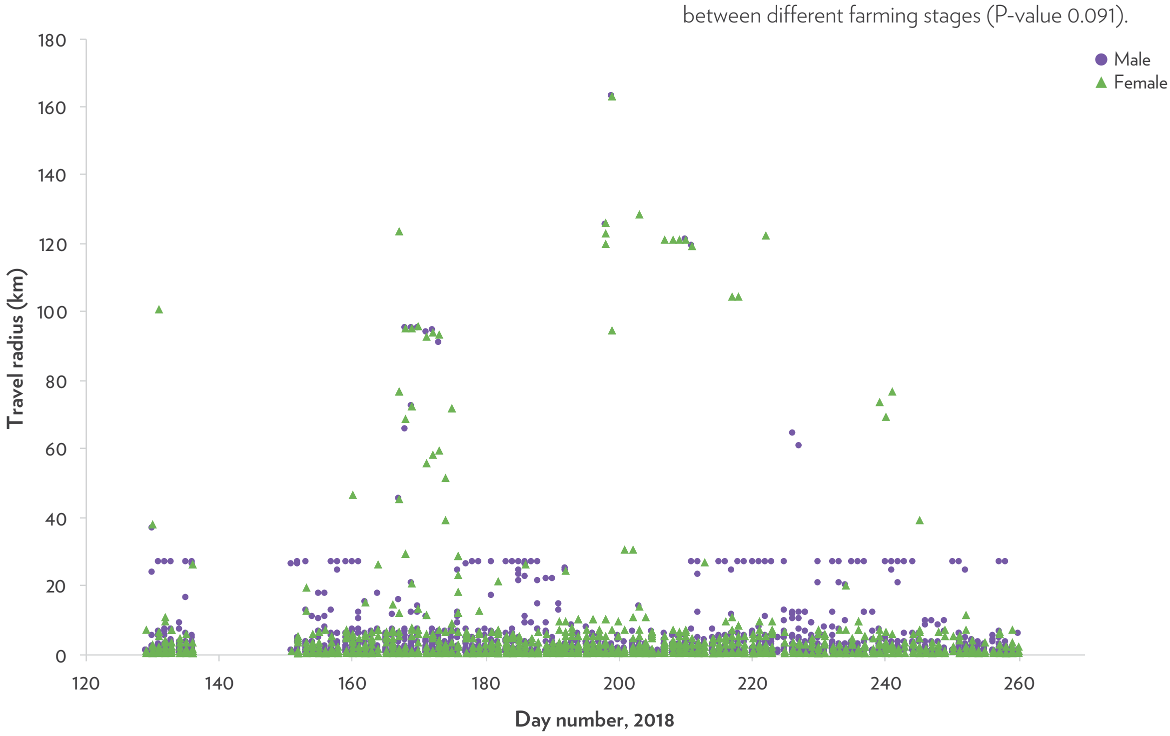


FIGURE 19 Men and women's travel radius during all farming stages

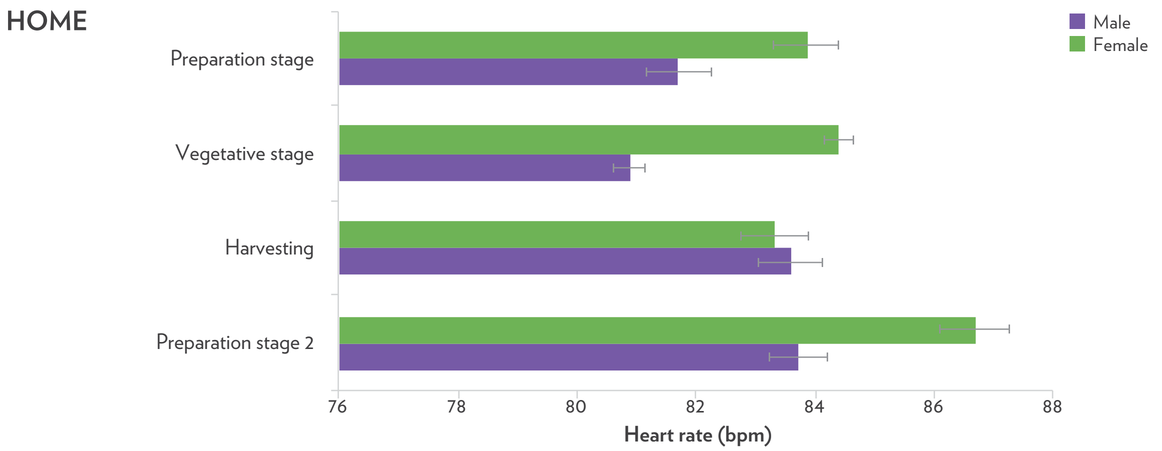


FIGURE 20 Average heart rates for men and women at the household/home over the agricultural cycle

Figure 21 shows the average heart rate of men and women in the paddy fields. The measure of heart rate has been used as a proxy for workload estimation. Both men and women have higher heart rate levels at the paddy field than at home, which is what might be expected since more heavy labour is done in the fields. Women appear to have higher average heart rates than men during the preparation and vegetative stages of the agricultural cycle. This may reflect peak planting when women are busier in the fields than men, whilst during the harvesting stage, men are busier in the field than the women.

Another way to examine work rate and physical activity by heart rate is using the percentage of time for men and women spent in 'light', 'moderate' and 'high/vigorous' work rate categories. We can use the work rate 'HRw' to estimate the percentage of waking time (excluding sleeping hours) spent in the different 'intensities' of work rate/physical activity.

Figure 22 shows the percentage of time (during waking hours) spent in the 3 categories of work rates — light, moderate, vigorous on average throughout the agricultural cycle. There is no statistically significant difference in the percentage of time spent in the different categories of work intensity between men and women. So, women have similar workloads to men throughout the season.

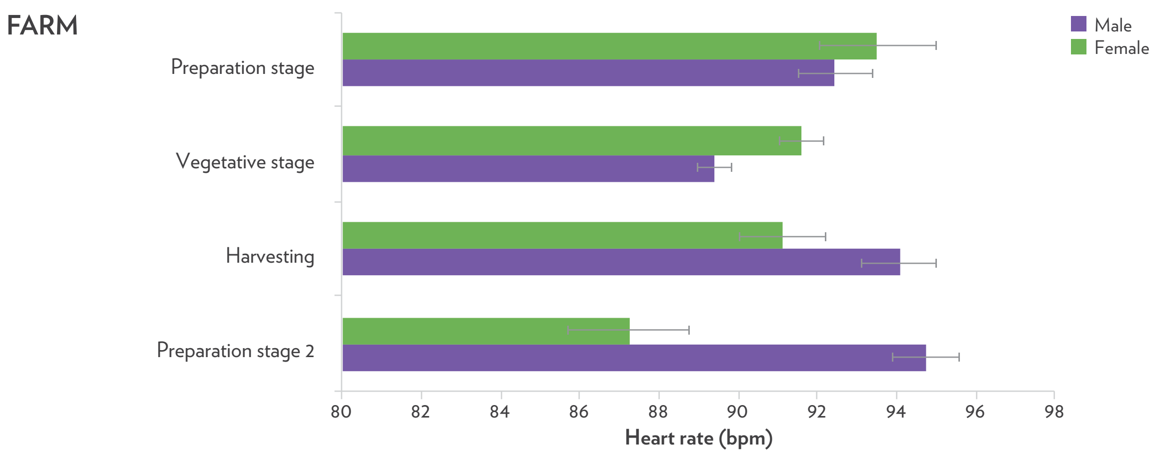


FIGURE 21 Average heart rates for men and women at the farm over the agricultural cycle

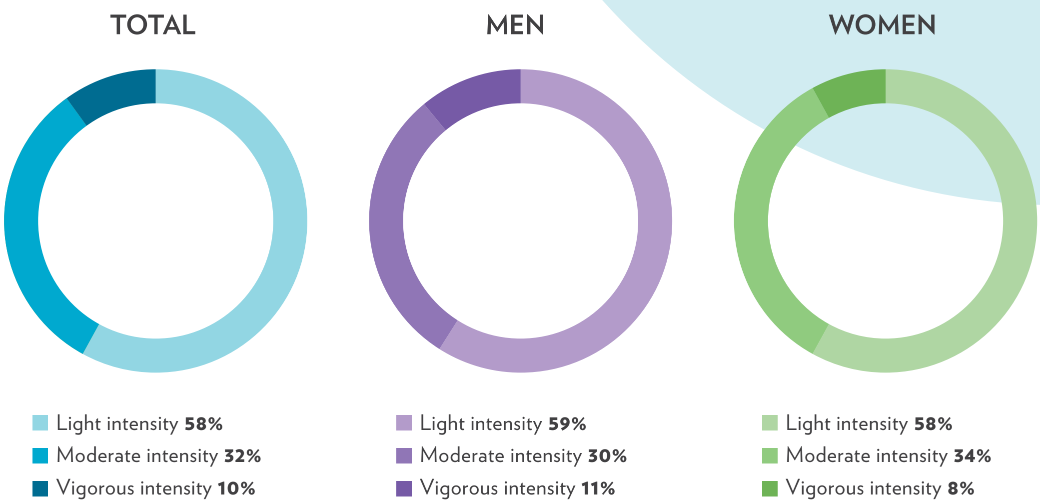


FIGURE 22 Percentage of time spent in the different categories of work rate

The percentage of time spent in activities of 'light', 'moderate' and 'vigorous' have been estimated for different phases of the agricultural cycle. Among the participants, men spent slightly higher time in vigorous work rates (11%) than women (8%). Men spent more time in vigorous work rates and women spent more time in moderate intensity work rates at every farming stages (Figure 23).

Based on statistical analysis, HRw does not differ significantly among men and women in the different categories of 'light', 'moderate' 'heavy/vigorous'. Female farmers exert working intensities that are comparatively similar with their male counterparts and are not significantly different. However, women undertake higher physical activity work rates in the home (possibly due to domestic chores and looking after family).

Figure 23 shows the percentage of time spent in the 'light', 'moderate' and 'vigorous' work rates at different farming stages. Men spent more time in vigorous work rates in all the farming stages, compared to women; whereas women spent more time in moderate intensity work rates in all farming stages.

4.3.6 Sleeping patterns

The following sleep variables were collected from the Garmin devices for sleep analysis

- 'durationInSeconds': Length of the sleeping period in seconds
- 'activeTimeInSeconds': a portion of the monitoring period in which wearer is considered active. This relies on heuristics internal to each device
- 'deepSleepDurationInSeconds': Time in seconds the user spent in deep sleep during the sleep period
- 'lightSleepDurationInSeconds': Time in seconds the user spent in light sleep during the sleep period
- 'awakeDurationInSeconds': Time in seconds the user spent awake during the sleep period

Only the participants with more than 60% data completeness are included in this analysis (57 out of 60 participants). The average sleeping duration of participants is 6 hours and 50 minutes. Based on the Garmin data, women sleep 3% longer duration than men, but this is not significantly different. Women sleep about 6 hours and 56 minutes, whereas men sleep about 6 hours and 43 minutes. The average bedtime and waking time for women are 21:10 and 04:06, and men's average bedtime and waking time are 22:03 and 04:49 respectively. As a result, men go to bed later and rise later.

4.3.7 Case studies

Whilst the above sections presents data for all participants that have been aggregated to examine averages and general trends in workload and activity patterns/mobility, the real benefits and advantages to using the wearables and smartphone technology is being able to monitor at an individual level (providing very detailed measures for individual farming households). The advantage is the ability in future to monitor the impact of changes in agricultural practice or policy at the individual level.

To illustrate the utility of using the Smartphone and Google GPS location process at an individual and household level, the following case studies have been included. Timelines of activity and location can be devised that give a detailed picture of activity patterns throughout the day. The following timelines depict activities for both men and women for three different households (Figure 24 to Figure 26).

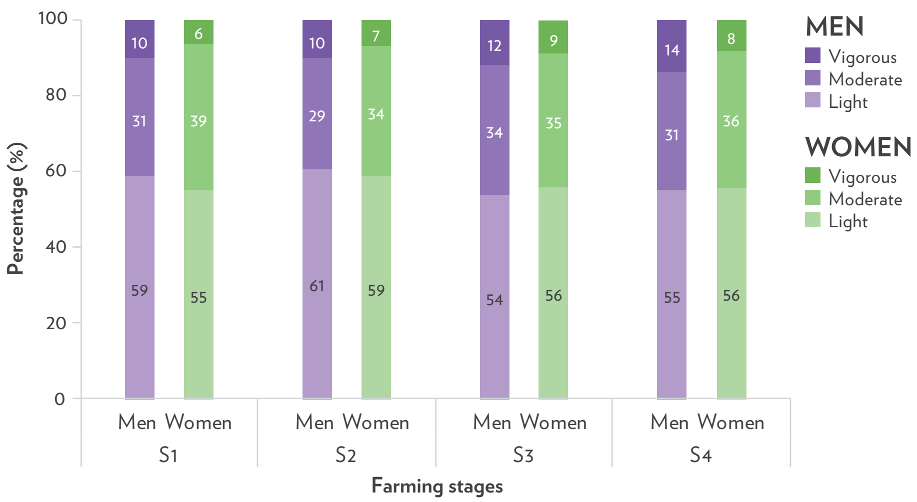


FIGURE 23 Percentage of time spent in the different categories of work rate at each farming stage

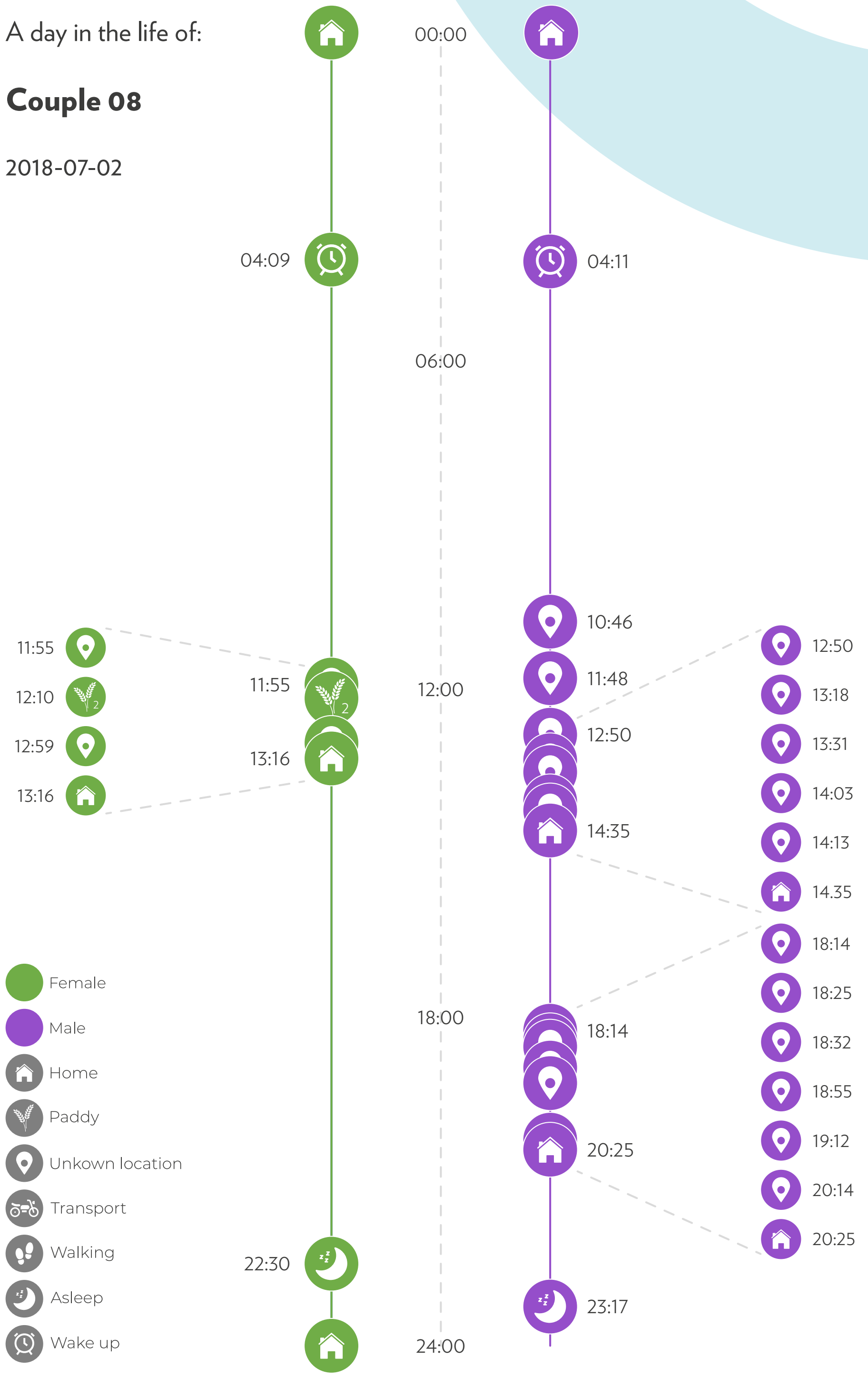


FIGURE 24 A day in the life of couple 8 (timeline)

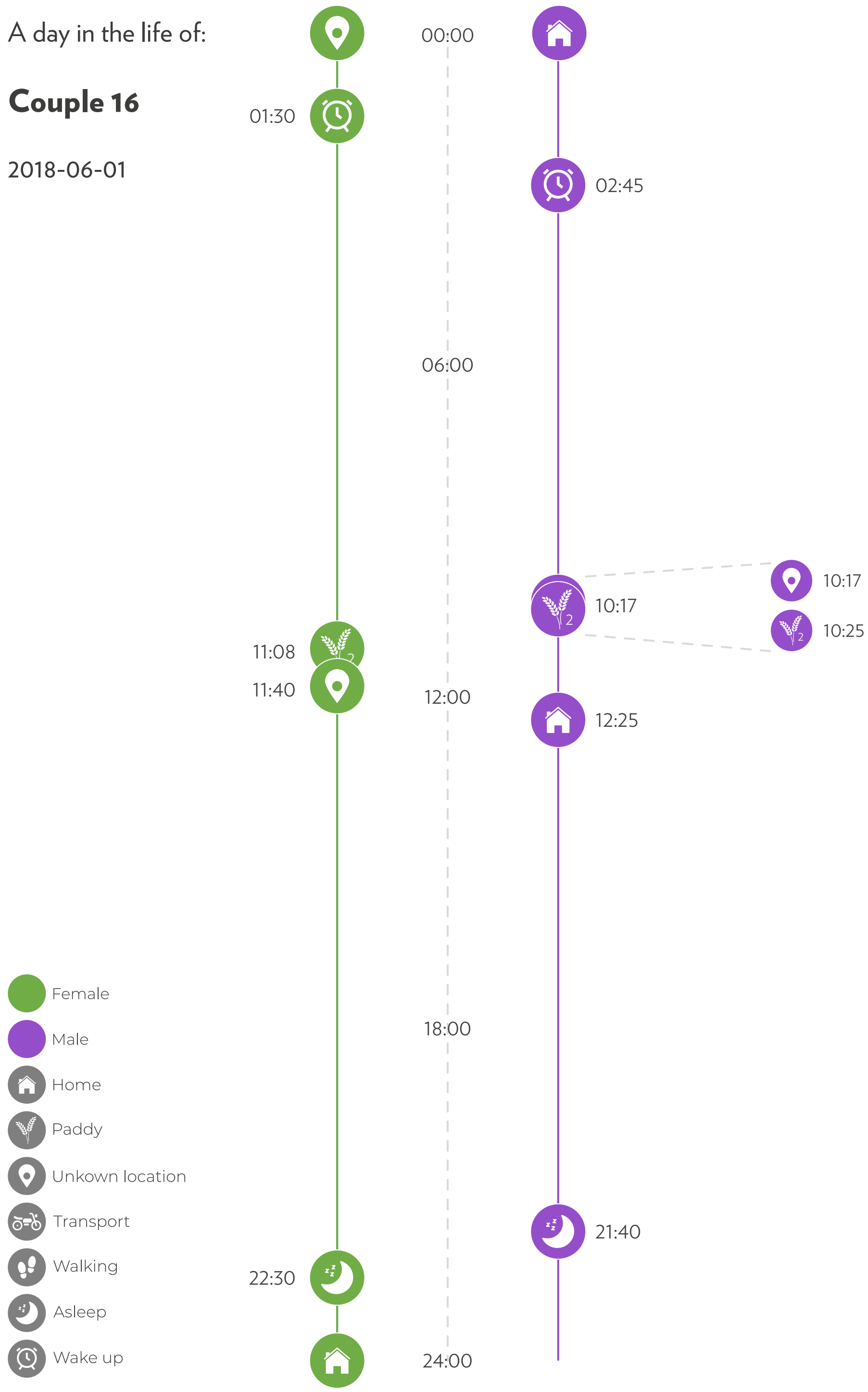


FIGURE 25 A day in the life of couple 16 (timeline)

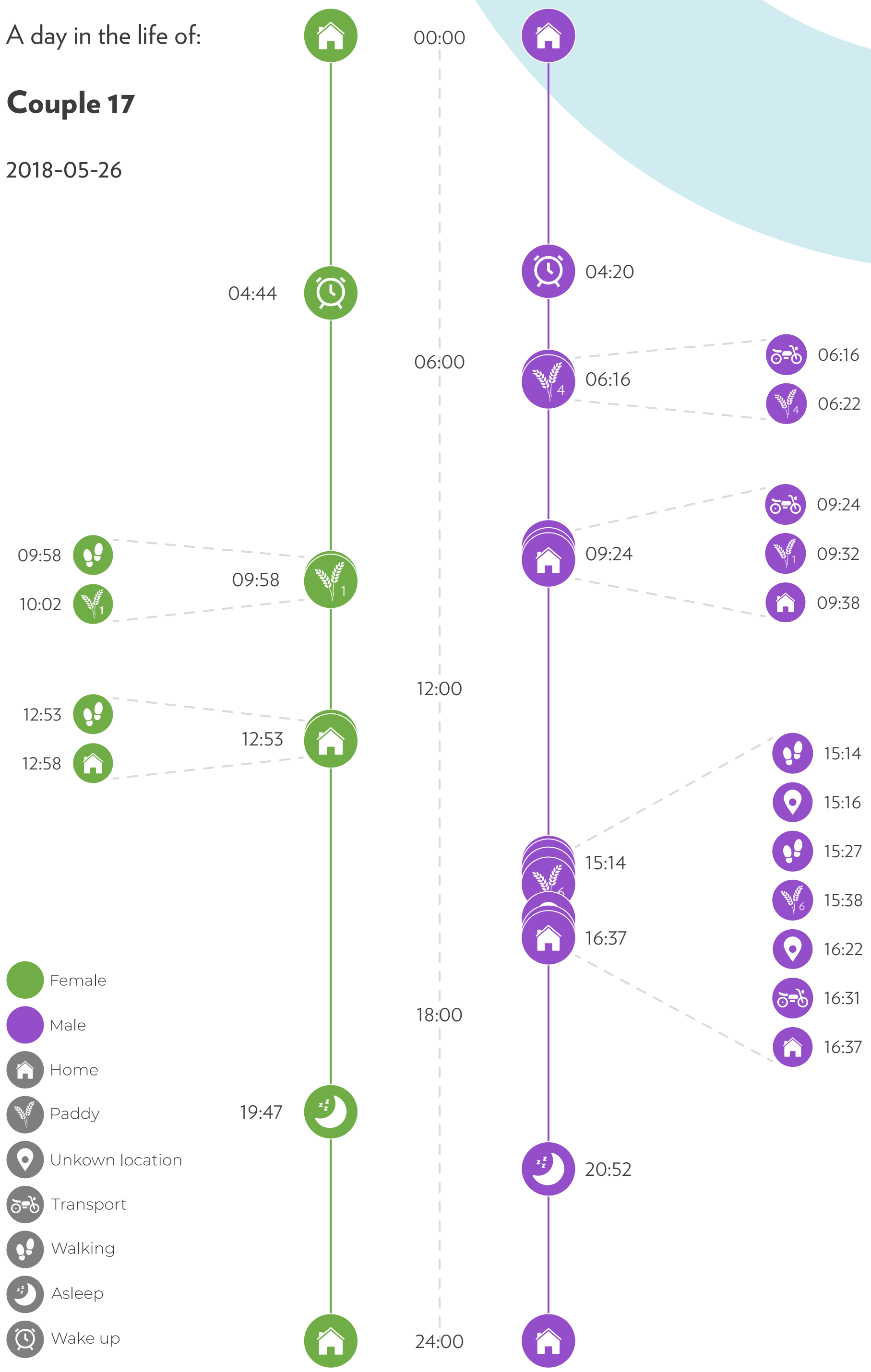


FIGURE 26 A day in the life of couple 17 (timeline)

4.3.8 Trend analysis

Visual data analysis can also be used to illustrate further detailed daily activity patterns as shown in Figure 27.

Each circular data visualisation combines data for both men and woman in the farming couple and can be illustrated for each stage of the agricultural cycle (Figure 28). The following assumptions are made to create a real-time graphic:

- Each circle represents data from 1 season, presented on a 24-hour clock
- The woman's data is plotted within the smaller inner circle and the man's data in the outer circle; the black line separates the two.
- The woman (green circle) and man (purple circle) represent activity data from Garmin, a high opacity means the behaviour is more frequent.
- The background colours represent locations, orange is the 'Home' and blue is the 'Farm'. Grey surfaces represent 'other locations' and white indicates missing data.
- Diagonally striped surfaces indicate sleep time and duration.

By visually investigating the 4 plots in Figure 28 we can conclude the following for farming couple number 22:

- During the preparation stage 1, the man visited the farm quite consistently between 09:00 and 20:00 (green surface). However, during these visits, we do not see many step counts (blue circles are small and low opacity).
- During preparation stage 1 the man and woman were physically active throughout the whole night on a few occasions.
- During the vegetative stage, both the man and woman were most active from 07:00 to 14:00 and from 17:00 to 21:00 (high opacity and high diameter).
- During the vegetative stage, the man frequently visited the farm between 09:00 and 13:00 (green surface), during this time he also accrued the most steps and had a high motion intensity.
- For preparation stage 2 we are missing location data for the woman, most of her circle surface is white. We do see that her activity was consistent from 08:00 until 22:00.

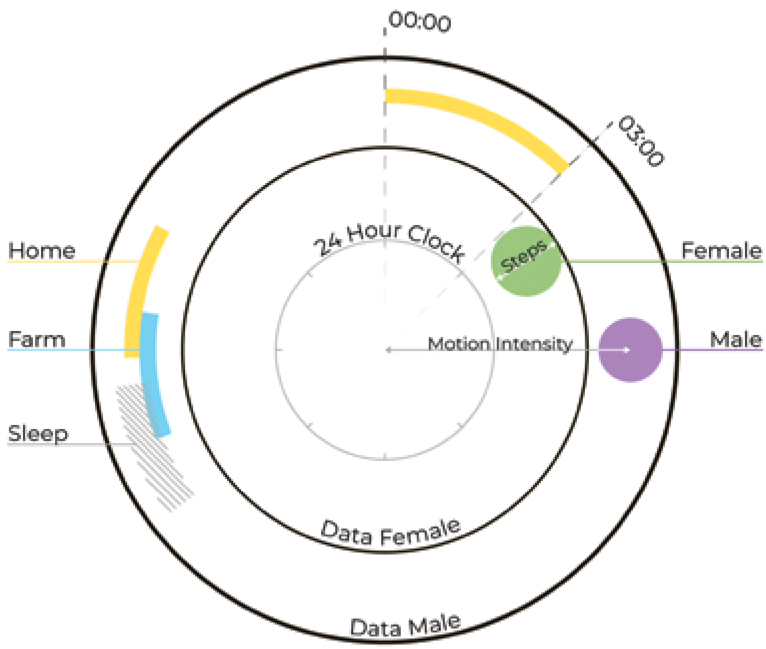


FIGURE 27 Visual trend analysis

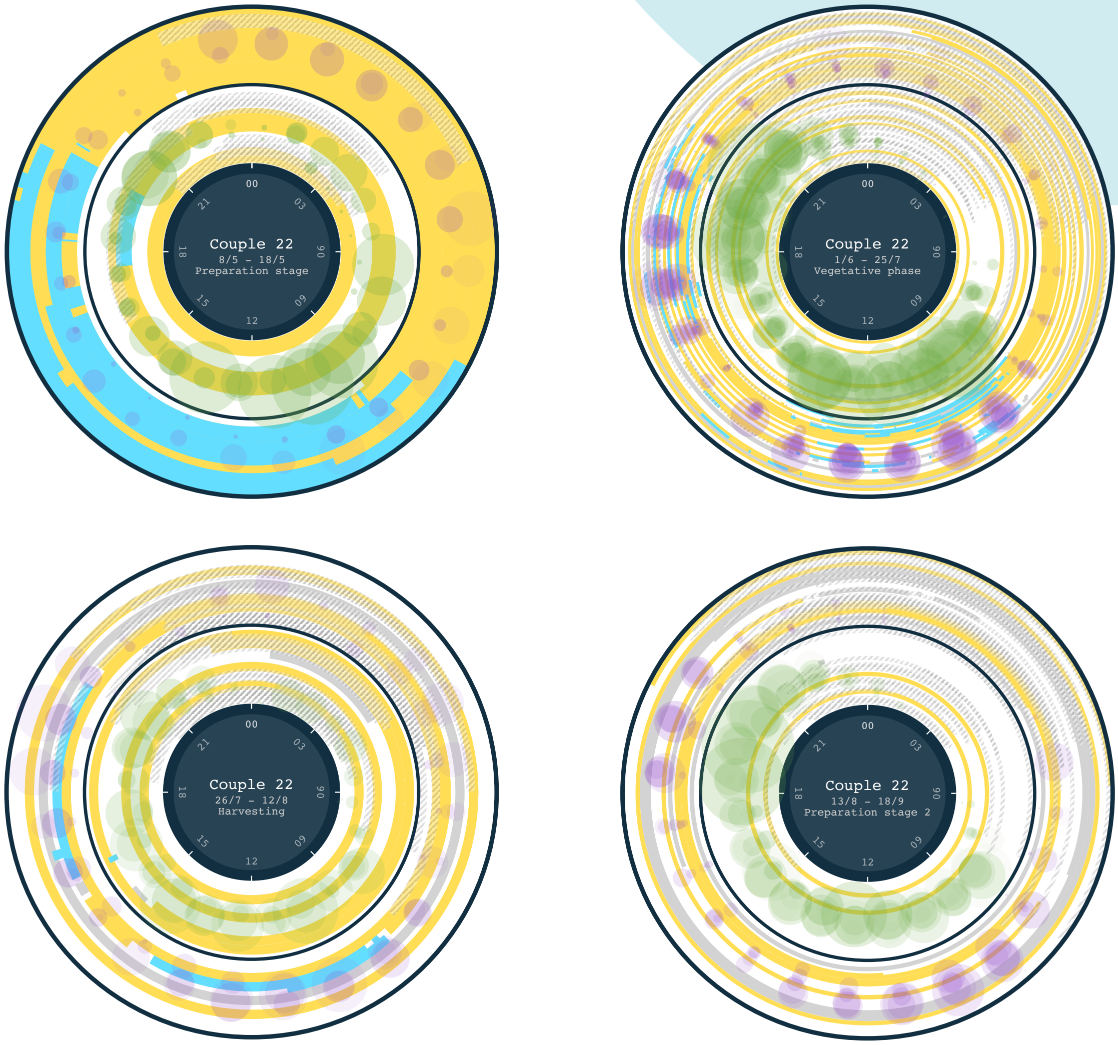


FIGURE 28 Visual trend analysis for farming couple ID 22 during the four stages of the agricultural cycle

This visual analysis shows differences between the two farming couples and between the man and woman in 'real time'. There is potential in future to make these interactive, so researchers can explore data and find interesting behaviours to investigate further. From Figure 29, we can conclude the following regarding the couple ID 30,

- Man visited the farm more often in preparation stage 2 compared to the other stages, between 09:00 to 21:00.
- Woman spent lesser time in the farm, compared to the man (fewer blue circles with less opacity).
- In the vegetative stage, both man and woman are consistently active from 08:00 to 00:00 (high opacity green & purple circles).
- Both man and woman had fewer hours of sleep in preparation stage 1 than other farming stages.

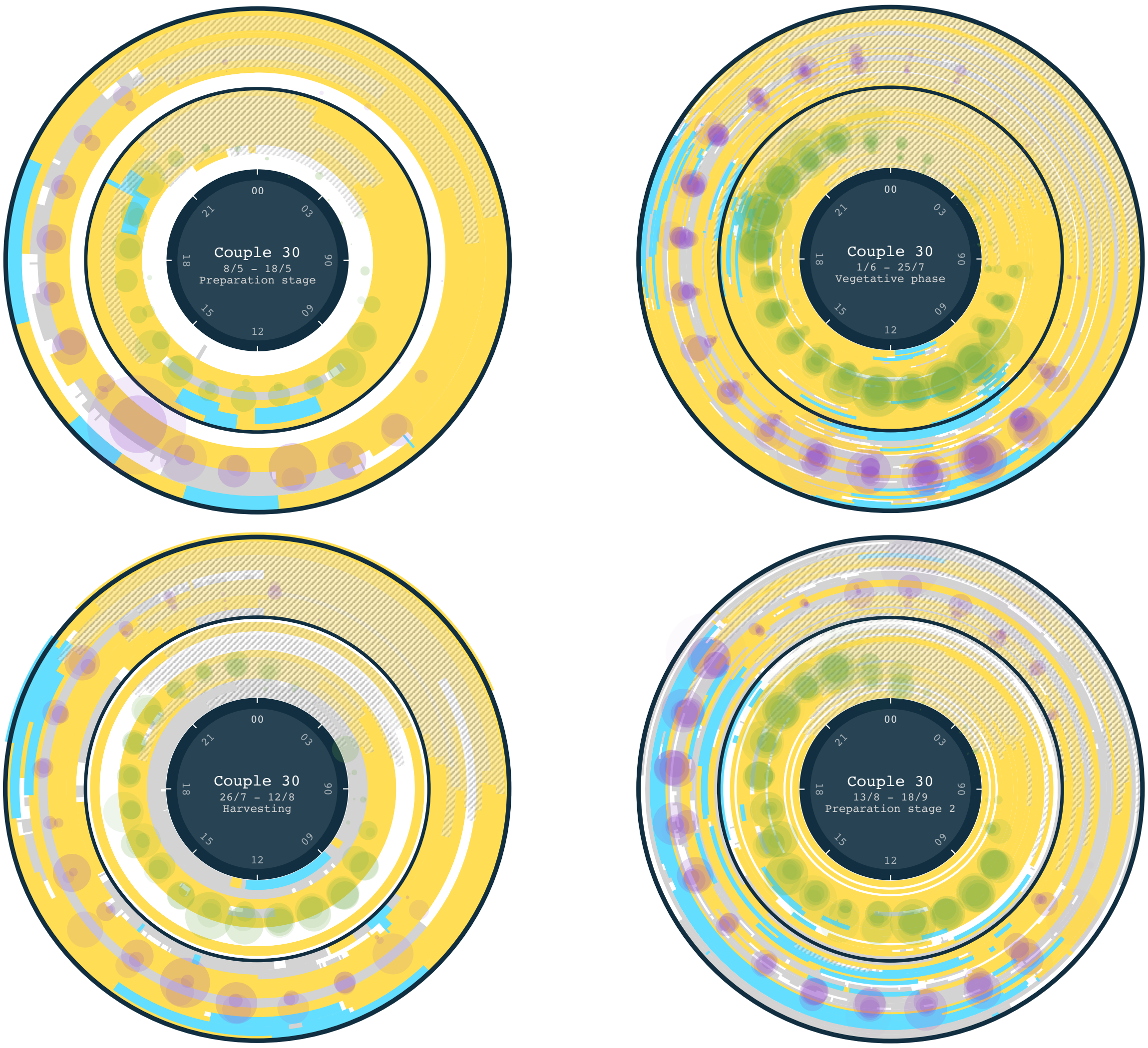


FIGURE 29 Visual trend analysis for couple ID 30 during the four stages of the agricultural cycle

4.4 FOCUS GROUPS – QUALITATIVE ANALYSIS

Focus group discussions (FGD) were conducted by the enumerators to:

1. Explore the daily activity of the participant, which includes: farming, household activity, community activity, and other.
2. Compare the daily activity between male and female farmers, and identify the differences between those two groups.
3. To compare results from focus group discussions with those objectively measured daily activity patterns and workload.

Two FGDs were conducted separately for men and women.

The first FGD was conducted on 12–13th July with 9 males and 8 female farmers in two different locations. The summary findings of first FGD:

- Male participants went to the rice-field more frequently than female farmers. A few of the men go twice a day, in the morning and after the lunch break. But farmers who work on several jobs e.g. sand-mining or construction labour, they only visit the field in the morning, or only 2–3 times a week. Male farmers spent most of their time in the house resting or undertaking a communal activity or hanging around in the local coffee shop. Female farmers went to the rice-field in the morning for weeding and doing some work to help their husband. Weeding is also considered a heavy activity for both male and female participants. Female farmers take the lead in managing the household needs and take care of the kids (e.g. taking them to the school).

The second FGD was conducted in 18th of August with 10 males and 9 female farmers. The summary findings of the second FDG:

- Both male and female farmers took turns to guard the rice against birds, some also asked their family members to do this. During harvesting stage, male farmers cut the paddy and lift the rice sacks, which is perceived as the heaviest work during harvesting stage. Some participants stayed until late to finish the harvest activity and do that for the whole week. Female farmers are helping the male farmers during the harvest and possibly have higher work intensity.

After the harvest, female farmers undertake farm activity in their house by sun-drying the rice grain, while male farmers can continue harvesting in the field.

From the comparison shown in Table 4, we can surmise that the focus group data helps validate the data collected by the wearable and smartphone devices in terms of working intensity, activity/movement patterns, the frequency of farm visits, and time spent at each location. However, there is a limitation in identifying the type of activity, this could be improved by developing a simple diary app' for the participants to use.

Table 4 illustrates a comparison between data obtained from focus groups with data collected by the objective measures (activity wearables, smartphone app and GSP). In terms of testing the reliability of the participant's perceptions in FGD and questionnaires and comparing with objective measures, more research is required since there are some discrepancies. Further studies would be required to fully validate perceptions against objective measures.

TABLE 4 Summary findings of the focus group discussion

		# Rice field visit		Time spent		Type of activity		Movement radius		Intensity	
FGD result	**Date**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Vegetative	12–13 July	Higher		Higher		Higher			Perhaps higher	Perhaps similar	Perhaps similar
Harvest	18-Aug	Higher		Higher		Higher			Perhaps higher	Higher	

		# Rice field visit		Time spent		Type of activity		Movement radius		Intensity	
Interview		**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Vegetative	25-Jul	N/A	N/A	Higher		Higher			Higher		Higher
Harvest	8-Aug	N/A	N/A	Higher		Higher		Similar	Similar	Similar	Similar

	# Rice field visit		Time spent		Steps		Movement radius		HR average		HR max	
	M	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Prep 1 (we missed the land prep and sowing)	Higher		Similar	Similar	Higher			Higher		Higher	Higher	
Vegetative	Higher			Higher	Similar	Similar		Higher		Higher	Higher	
Harvest	Higher		Higher		Higher			Higher	Higher		Higher	
Prep 2 (data collection only until sowing)	Higher		Similar	Similar	Higher		Higher		Higher		Higher	

In terms of testing the reliability of the participant's perceptions in FGD and questionnaires and comparing with objective measures, more research is required since there are some discrepancies. Further studies would be required to fully validate perceptions against objective measures.

> *i* **Findings from focus group discussions with men and women farmers have helped to validate the use of wearables and smartphone technology. The wearable devices allow better measurement and allow more accurate comparisons in estimating workloads and activity patterns between female and male farmers.**
>
> **Specifically, the technology can monitor in much more detail than previously used methods. Using the wearable and smartphone technology enables monitoring and quantification of work rate and activity patterns in 'real time and place' and at the group and individual level.**

5. LIMITATIONS AND DISCUSSION

By using smartphone technology with Gamin activity wearables and GPS location devices, we have been able to objectively monitor in detail varying workloads, physical activity and mobility patterns in a group of rural rice farmers over several phases of the agricultural cycle. The acceptability and participant adherence to using the technology daily was very high, with a low dropout rate over a 5-month period. No adverse reactions to wearing the wrist devices were reported. A practical implementation process was established successfully, and an IT platform form developed that was secure and easy to use. A range of novel data analytics and visualisations were used to illustrate farming workload and location of activity patterns of groups of farmers and for individuals and farming households. However, there were several limitations to the study that should be noted:

- **Third-party services**

  The Garmin, Google Fit and Moves apps are all third-party services. Therefore, the research team did not have any control as to the algorithms used to interpret data. When the service provider releases a software update, these algorithms can sometimes be changed, leading to slightly different pre-processing of the raw data. This could influence the data parameters to receive through the respective API (Garmin, 2018).

- **Limitation of the location-based analysis**

  The Moves app' was the preferred method for capturing places visited for this study. However, researchers had to switch to using GoogleFit during the study due to the discontinuation of the Moves App. Moves app was preferred because it works with motion-based triggers. E.g., Moves knows when the user is active and accurately knows when the phone leaves or arrives at a location. Unlike Moves, GoogleFit samples either at random or by using location-based triggers, which is not as sensitive or as accurate as motion-based triggers.

- **Limitations of the FGD and questionnaire**

  There were several limitations to the FGD and questionnaire in terms of testing the validity of self-reported measures;

  — questions use in the survey items were not specifically comparable to those measured objectively

  — some data was missing in the FGD on the phases of the agricultural cycle

  Further follow on studies are required to fully validate perceptions against objective measures of workload using comparable items in questionnaires that relate specifically to objectively measured variables.

- **Cost of wearables and smartphone**

  Use of the technology for a larger population may be too expensive however, cheaper activity wearables are coming on the market which are more affordable and better location/GPS apps' that are free are being developed by researchers.

6. CONCLUSION

In terms of testing the use of IT wearable devices, smartphones and apps', this feasibility study has successfully demonstrated the potential of measuring objectively and in 'real-time' workload and activity patterns of men and women rice farmers over a 5-month period of the agricultural cycle. Uptake and adherence to wearing the activity monitors and using the smartphones and apps' was extremely high and acceptable to both men and women rural farmers in Indonesia.

The relative workloads (heart rates) and activity patterns (GPS monitoring and step counts) of women and men could be monitored and quantified at both the individual, household and community level. Although gender workloads differ depending on cultivation stage, initial findings show that overall, women exert heart rate intensities/workloads that are similar to men. Women on average spend similar amounts of time during the day in heart rates in the 'light', 'moderate', 'vigorous/high' categories as men. Women also undertake considerably higher physical activity work rates in the home compared to men, thus supporting the 'triple burden concept'.

Further studies are recommended to validate self-reported workload and perceptions with objective measures. Further, the development of improved GPS location tracking apps', use of METs for measuring workload intensity, and greater in-depth FGD with the inclusion of directly comparable questionnaire items with objective measures should be considered for future research.

The novel use of smartphones and wearable sensors has the potential to make direct objective, empirical observations of respective work load and activity patterns and locations in 'real time' and to monitor the impact of changes in policy/practice on work load/work patterns on men and women farmers. This could also be used for comparison of sub-populations or communities from different regions or countries.

The use of wearable devices, GPS tracking and smartphones has potential to monitor the impact of changes in agricultural practice or policy at the individual or community level.

7. FUTURE STUDIES

For future studies, it would be better to collect data through our own applications. For GPS data this will be possible through Onmi's new 'Luka' application which is currently in development. Luka works with motion-based triggers and can identify when the user is active, and when the phone leaves or arrives at a specific location. It can also classify mode of transport between locations. It would also be better to estimate the Metabolic Equivalent of Task (MET), which is an official measure of activity intensity as well as heart rate. Calculation of MET is an estimation based on the biometric data provided (height, weight, age, gender) and can help quantify workload more precisely.

Developing an app' that does not require constant internet access to store data and better geo-tagging capacity so that the type of activity for each participant (at specific locations) can be monitored, would be of benefit.

Overall, this feasibility study has demonstrated that the novel use of technology can help to monitor and quantify in detail and in real time and place, work rates, activity patterns and mobility of men and women rural farmers. This has much potential for future studies examining objectively, the impact of changes in agricultural practice and policy in individual farmers or for a community.

8. ACKNOWLEDGMENT

Acknowledging the significant but somewhat uneven economic growth in Indonesia over the past 15-20 years, the Government of Indonesia has partnered with the Government of Australia on the AUD 112 million Australia-Indonesia Partnership for Rural Economic Development investment (AIP-Rural), a suite of programs focused on boosting the incomes of smallholder farmers by improving their access to new markets, better inputs, knowhow, technology, irrigation and small loans. The first phase ended in December 2018 and increased incomes of over 300,000 smallholder farmers households, while PRISMA-2 aims to achieve a sustainable 30% increase in the net incomes of one million smallholder farming households in eastern Indonesia by 2023.

AIP-Rural's four investments have a unified purpose, but distinct goals and approaches: PRISMA (Promoting Rural Income through Support for Markets in Agriculture) aims to remove growth constraints in particular agricultural commodities important to smallholder farmers (e.g. beef, cocoa, coffee, maize); TIRTA (Tertiary Irrigation Technical Assistance) aims to increase farmer access to tertiary irrigation by facilitating private investment in this sector, SAFIRA (Strengthening Agricultural Finance in Rural Areas) supports existing financial institutions to expand their portfolios of agricultural finance to smallholders, and are all implemented by Palladium and Swisscontact; and ARISA concentrates on the commercialisation and dissemination of agricultural innovations which will have an impact on smallholder agriculture (co-funded by DFAT and CSIRO, and implemented by CSIRO).

REFERENCES

1 AIP-R 2017. AIP-Rural Gender Inclusion Strategy: Empowering Women in Agriculture in Indonesia.

2 AIP-RURAL. 2018. *Australia-Indonesia Partnership for Rural Economic Development* [Online]. Available: **https://aip-rural.or.id/en/about-us** [Accessed 2018 February 8].

3 BORAH, R. & KALITA, M. 2016. Physiological workload and postural stress of farm women in the harvesting of paddy grains. *International Journal of Applied Home Science*, 3, 205–213.

4 BORAH, S. 2015. Physiological Workload of Hill Farm Women of Meghalaya, India Involved in Firewood Collection. *Procedia Manufacturing*, 3, 4984–4990.

5 BOULDING E. Familial Constraints on Women's Work Roles, Signs: Journal of Women in Culture and Society 1, no. 3, Part 2 (Spring, 1976): 95–117.

6 BROWN, S. 2003. Spatial Analysis of Socioeconomic Issues: Gender and GIS in Nepal. *Mountain Research and Development*, 23, 338–344.

7 BRYCESON, D. F. & HOWE, J. 1993. Rural household transport in Africa: reducing the burden on women? *World Development*, 21, 1715–1728.

8 CHIONG-JAVIER, M. 2009. Health Consequences of Rural Women's Productive Role in Agriculture in the Philippines and Other Developing Countries. *Journal of International Women's Studies*, 10, 95–110.

9 CROSBIE, T. 2006. Using Activity Diaries: Some Methodological Lessons. *Journal of Research Practice*, 2, 1–13.

10 DFAT. 2013. *Summary Design Document — Promoting Rural Income through Support for Markets in Agriculture* [Online]. Department of Foreign Trade & Affairs Available: **https://dfat.gov.au/about-us/publications/Documents/promoting-rural-outcomes-strengthening-markets-ag-prisma-design-doc.pdf** [Accessed February 9 2018].

11 DFAT. 2014. *Tertiary Irrigation Technical Assistance (TIRTA) Design Document* [Online]. Department of Foreign Affairs & Trade. Available: **https://dfat.gov.au/about-us/publications/Documents/tertiary-irrigation-technical-assistance-tirta-design-doc.pdf** [Accessed February 9 2018].

12 DFAT 2015. Gender equality and women's economic empowerment in agriculture. *Operational Guidance Note.* Canberra: Department of Foreign Trade and Affairs.

13 ESTER, M., KRIEGEL, H., SANDER, J. & XU, X. A Density-Based Algorithm for Discovering Clusters in Large Spatial Databases with Noise. Knowledge Discovery and Data Mining 1996 Germany University of Munich, 226–231.

14 FAO. 2011. The Role of Women in Agriculture. *ESA Working Paper* [Online]. Available: **www.fao.org/docrep/013/am307e/am307e00.pdf** [Accessed February 3, 2018].

15 FAO. 2017. The State of Food and Agriculture: Leveraging Food Systems for Inclusive Rural Transformation. Rome.

16 GOOGLE. 2018. *Google map developers* [Online]. Available: **www.mapdevelopers.com/free-mapping-service.php** [Accessed 30th October 2018].

17 GROBORZ, A. & JULISZEWSKI, T. 2013. Comparison of farmers workload by manual and mechanical tasks on family farms. *Annals of Agricultural and Environmental Medicine*, 20, 356–360.

18 HABIB, R., HOJEIJ, S. & ELZEIN, K. 2014. Gender in occupational health research of farmworkers: A systematic review. *American Journal of Industrial Medicine*, 57, 1344–1367.

19 HABY, M., CHAPMAN, E., CLARK, R., BARRETO, J., REVEIZ, L. & LAVIS, J. 2016. What are the best methodologies for rapid reviews of the research evidence for evidence-informed decision making in health policy and practice: a rapid review. *Health Research Policy and Systems*, 14, 83.

20 IBM 2017. IBM SPSS Statistics for Windows. 25 ed. New York: IBM Corp.

21 IFAD. 2016. *Reducing rural women's domestic workload through labour-saving technologies and practices* [Online]. Rome: International Fund for Agricultural Development. Available: **www.ifad.org/documents/38714170/40196082/Teaser_workload_web.pdf/c8b175be-f4cf-4f97-a3bf-d6720cc08aaf** [Accessed February 5 2018].

22 JONES, L. 2016. Women's Empowerment and Market Systems: Concepts, practical guidance and tools (WEAMS Framework). London: BEAM Exchange.

23 JOSHI, P., JETHI, R., CHANDRA, N., ROY, M., KHARBIKAR, H. & ATHEEQULLA, G. 2015. Ergonomics Assessment of Post-Harvest Finger Millet Threshing for reducing Women Drudgery. *Indian Research Journal of Extension Education*, 15, 25–30.

24 KHANGURA, S., KONNYU, K., CUSHMAN, R., GRIMSHAW, J. & MOHER, D. 2012. Evidence summaries: the evolution of a rapid review approach. *Systematic Reviews*, 1, 1–9.

25 KIM, E., YEON, S., LEE, S. & CHOE, J. 2015. Comparison of total energy expenditure between the farming season and off farming season and accuracy assessment of estimated energy requirement prediction equation of Korean farmers. *Nutrition Research and Practice*, 9, 71.

26 MOHAMMED, E. 2014. Women' workload and their role in agricultural production in Ambo district, Ethiopia. *Journal of Development and Agricultural Economics*, 6, 356–362.

REFERENCES

27 NAG, A. & CHINTHARIA, S. 1985. Physical activities of women in farming and non-farming seasons. *Journal of Human Ergology*, 14.

28 OSBORNE, A., BLAKE, C., FULLEN, B., MEREDITH, D., PHELAN, J., MCNAMARA, J. & CUNNINGHAM, C. 2011. Risk factors for musculoskeletal disorders among farm owners and farm workers: A systematic review. *American Journal of Industrial Medicine*, 55, 376–389.

29 RAHMAN, F. H. 1993. Not a burden but a force. *International Agricultural Development*, 11–12.

30 SHARMA, B., VERMA, S. & MUSTAFA, M. 2017. Ergonomic Evaluation of Drudgery Load Faced by Farm Women in Wheat Harvesting. *International Journal of Current Microbiology and Applied Sciences*, 6, 3014–3022.

31 SHELTON, B. & JOHN, D. 1996. The division of household labour. *Annual Review of Sociology*, 22, 299–322.

32 SHEPHARD, R. 2003. Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine*, 37, 197–206.

33 SIEGMANN, K. Globalisation, Gender, and Equity: Effects of Foreign Direct Investment on Labour Markets in Rural Indonesia. German Development Economics Conference, 2007 Germany. Research Committee Development Economics.

34 SINGH, A., GAUTAM, U. S., SINGH, R. & PALIWAL, D. 2014. Ergonomic study of farm women during wheat harvesting by the improved sickle. *African Journal of Agricultural Research*, 9, 1386–1390.

35 SINGH, D. & VINAY, D. 2014. Ergonomic assessment of traditional and improved methods of paddy threshing for drudgery reduction of hill region. *Journal of Food, Agriculture & Environment*, 12, 244–250.

36 SINGH, P. & JOHN, S. 2017. Role of Women in Agriculture. *International Journal of Multidisciplinary Approach and Studies*, 4, 25–30.

37 SINGH, S. 2015. Physiological Workload of Women Agricultural Labourers in Selected Activities in Indian Maize Cultivation. *Journal of The Institution of Engineers*, 96, 21–25.

38 SINGH, S. 2016. A number of workers for assessing physiological workload while operating farm equipment. *Agriculture engineering today*, 40, 36–41.

39 SU MUSTAFFA, C. & ASYIEK, F. 2015. Conceptualizing Framework for Women Empowerment in Indonesia: Integrating the Role of Media, Interpersonal Communication, Cosmopolite, Extension Agent and Culture as Predictors Variables. *Asian Social Science*, 11, 225–239.

40 TRICCO, A., ANTONY, J., ZARIN, W., STRIFLER, L., GHASSEMI, M., IVORY, J., PERRIER, L., HUTTON, B., MOHER, D. & STRAUS, S. 2015. A scoping review of rapid review methods. *BioMed Central Medicine*, 13, 224.

41 UN 2005. Guide to producing statistics on Time use: Measuring paid and unpaid work. United Nations.

42 WICKEL, E. E. 2014. Reporting the Reliability of Accelerometer Data with and without Missing Values. *PLoS One*, 9.

43 WORLD BANK 2012. Promoting Women's Agency. *World Development Report 2012: Gender Equality and Development*.

LIST OF FIGURES AND TABLES

LIST OF ABBREVIATIONS

AIP-Rural: Australia-Indonesia Partnership for Rural Economic Development

ARISA: Applied Research and Innovation Systems in Agriculture

AvgHR: Average heart rate

CSIRO: Commonwealth Scientific and Industrial Research Organisation

FAO: Food & Agriculture Organization

DFAT: Department of Foreign Trade & Affairs

HR: Heart rate

HRw: Work rate (Average heart rate calculated during waking hours)

HRmax: Maximum heart rate

HRr: Resting heart rate

HRd: Heart rate difference

ICATUS: International Classification of Activities for Time Use Statistics

Km: kilometres

M: metres

M4P: Making Markets Work for the Poor

MSD: Market Systems Development

PRISMA: Promoting Rural Income through Support for Markets in Agriculture

SAFIRA: Strengthening Agricultural Finance in Rural Areas

SIM card: Subscriber Identity Module card

SPSS: Statistical Package for the Social Sciences

TIRTA: Tertiary Irrigation Technical Assistance

UC: The University of Canberra

HEALTH RESEARCH INSTITUTE
University of Canberra
Locked Bag 1
University of Canberra
ACT 2601 Australia

To obtain a copy of the Supplementary Information, contact:
uchri@canberra.edu.au