Completion Report

Improved Business Through Seasonal Forecasting for Coffee in Vietnam, Vietnam, NCF7, NCF-C7-047

Grantee: University of Copenhagen

Local Partner(s): International Center for Tropical Agriculture (CIAT), Real-Time Analytics Company Limited (RTA), Atlantic Commodities Vietnam Ltd. (SMS-ECOM)

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1. EXECUTIVE SUMMARY

In 2018, we embarked on a mission to develop a new smartphone application to Robusta coffee farmers in the Central Highlands of Vietnam. Our goal was twofold: first, to address the lack of climate information services; and second, to provide timely agricultural advisory directly to farmers through a digital platform. By incorporating existing knowledge and best practices, we aimed to enhance climate adaptation and mitigation practices among coffee farmers. Ultimately, our efforts would lead to more climate-resilient coffee farms with the capacity to store additional carbon within the coffee ecosystems. The primary pathways for achieving this positive change involved reducing the use of inorganic fertilizer in what is among the world's most intensively managed coffee farms, as well as promoting increased uptake and storage of carbon in shade trees within coffee plots. Our chosen vehicle for achieving these goals was the smartphone app.

During the project, interviews were carried out with key stakeholders in the Vietnamese coffee sector and more than 400 coffee farmers in two provinces were surveyed, resulting in a farmers' needs database. Data analyses, combined with a literature review and farmer workshops, led to identification of best practices for climate mitigation and adaptation, their associated impacts on coffee yields, and identification of triggers for farmers' adaptation behaviour. Regional climate models for Vietnam, based on existing models and climate data sets and supplemented with data from weather stations, generated 3-months seasonal forecasts for temperature and precipitation in the Central Highlands. The forecasts and associated agricultural advisory for coffee practices, supplemented with shade tree advisory and yield-target-based advice on fertilizer applications, were integrated in an existing digital platform and smartphone application rtWork. A related trader-facing coffee yield forecasting module was cancelled due to lack of business interest in the module from the main coffee buying companies.

After substantial delay in project development due to Covid19, the app was disseminated at the beginning of the 2021-coffee season to a sample of farmers covering half of the baseline farmers. Workshops, farmer visits and telephone interviews were carried out to support the dissemination of the app. An impact assessment, based on an endline survey of farmers with and without the app, carried out after the 2021-22 coffee season, showed limited use of the app and adoption of advisory among farmers. Only minor changes in use of fertilizers between app-users and non-users were detected, leading to very modest savings in GHG emissions. As expected, no changes in management of shade trees were detected, as this is a longer term adaptation strategy.

Addressing a gap in advisory, seasonal forecasts are often perceived as complex scientific information and hard to interpret by various levels of users. The app has shown how we are able to translate and simplify complex seasonal forecasts into a tool, which bridges the gap between scientific information and practical recommendations. However, the process has also revealed important

considerations in app development and dissemination, and allowed us to identify that there may be more efficient ways of disseminating forecasts and related advisory, such as through trusted extension services, local input suppliers, or even television. Wefocos has made scientific information more actionable for farmers, who can adjust and adapt their management practices driving more sustainable farming and improved business. Going forward, the Wefocos project partners will discuss options for continuation of the seasonal forecast and the different modules of the app.

2. ACHIEVEMENT OF RESULTS

2.1 Achievement of outcomes and outputs

The table below details the outcomes and outputs related to the original results framework, with originally set targets shown in [ ].

Expected outcomes and outputs	**Indicators [and original targets]:**	**Achievement of outcomes and outputs:**
Outcome 1.1: Farmers' knowledge integration	Farmers knowledge Customised adaptation solutions [5]	Described below in output 1.1.1 to 1.1.3.
Output 1.1.1: Knowledge Database	Database of farmers' needs [1] - Gender specific needs Database of stakeholder needs [1] Number of (female) farmers participating in knowledge workshops [200 (100)]	A pilot survey of 76 coffee farmers resulted in a good understanding of farmers' needs and their context. A full baseline survey with 400 farmers, using rtWorks Survey platform, resulted in a large database with detailed information on all aspects of coffee farming, climate shocks and adaptation, access to information, livelihoods strategies, and farmer typology, incl. gender aspects as female and male farmers were interviewed in each household. A scientific article is published in the Journal of Agricultural and Resource Economics. During several rounds, workshops were carried out with close to 100 farmers (around half female farmers), lead farmers and agricultural technicians. Information was obtained in order to develop the format and design of the app for dissemination of Ag advisory and seasonal forecasts. An assessment was carried out of existing mobile applications to identify existing solutions on the market and gaps in climate services. Interviews with 11 coffee buyers/roasters helped to identify stakeholder needs in terms of yield forecasting. It turned out not to be of interest to the coffee buyers, who are already doing rough

		yield estimates based on flower/fruit counting during the farm visits. Therefore, it was not a viable venue to continue the yield forecasting modelling as part of the commercial services. A report and database of farmer and stakeholder needs were part of the MS1 progress report.
Output 1.1.2: Farmer baseline database	Baseline database [1]	Described above. The database is stored as an Excel file and is still being used for specific studies and data analysis. A farmer database report was part of the MS2 progress report.
Output 1.1.3: Recommendations and adaptation options	Set of novel site-specific recommendations and adaptation options [5]	Based on the baseline survey, the workshops with farmers and extension officers, and on a literature review, an extensive list of recommendations and adaptation options were described and subsequently made specific to the three main eco-agricultural types within the research area. Subsequently, the adaptation options [>10] were added to the mobile application. A report document and describing the adaptation options was part of the MS2 progress reporting. A scientific manuscript regarding site specific climate change adaptation strategies based on survey and workshop data is being developed.
Outcome 1.2: Better preparedness of smallholder farmers to climate change	Baseline farmers introduced to the app [200]. (originally phased as *subscribers to forecasting system*) Farmers' use of app and adoption of recommendations [100] (originally: *Adopters of recommendations*) Female farmers using the app services [500] (Originally: *females subscribed to the forecasting system [1000]*) Users per focus area/region [500] (originally: *subscribers*) Users of the forecasting system [2000] (originally: *users*	181 farmers from the baseline survey were randomly selected to receive the app. We succeeded to contact 161 farmers via farm visits and telephone calls. Many farmers did not have a phone, their phone was broken, or they had left the area or were no longer farming coffee. The remaining farmers received oral and/or written instructions on how to download the app. 56 farmers successfully installed the app and logged in to the system. An additional 85 farmers, not part of the baseline, were introduced to the app through workshops. No data exist on their use of the app. 22 farmers self-report to have actively used the different modules in the app, including the adaptation solutions. Analysis of the endline data shows no impact of app use on the number of adaptation measures implemented. However, app users on average had a lower use of fertilizer than the control group. While the control group increased fertilizer use in the endline season, the app users slightly decreased their use on average when taking into account the expected fertilizer

	subscribed to the climate forecasting system)	use based on coffee area and the endline season was a bulk coffee year (highly productive). The endline survey showed 10 active app users in Lam Dong and 12 active users in Dak Lak. 14 farmers specifically stated to use the forecasts and related agricultural advisory. Also see below.
Output 1.2.1: Accurate & reliable seasonal climate forecasting system	Reduction in seasonal forecast error [30 %]	Empirical weather data was complemented with several historical climate datasets, and the combined data was used to develop seasonal weather forecast models. The hindcast skill improved from 60 – 80% of earlier regional climate models to 80-90 %. The was verified with USQ / DeRisk information that compared our model to previous models.
Output 1.2.2: Set of associated decision support tools for farmers	Farmers implementing the adaptation solutions [50]	56 farmers installed the app. 22 farmers stated in the endline survey to have actively used (beyond reading content) the app and its different functions. More may have read content, such as fertilizer application amounts as indicated by the lower use of fertilizer among app users. One third of the farmers using the app (22) stated that it was either shared use of the app between husband and wife or the wife using the app. Additional farmers, outside the group of baseline farmers, may have adopted recommendations. This is not recorded.
Outcome 1.3: Shared value throughout the chain and long term ownership	New jobs created, including seasonal, also for women	With the nature of the project being a trial of the forecasting system and agricultural advisory via a farmer facing mobile application, it is not expected that new jobs have been created in the Vietnamese coffee sector or supporting sector directly as an outcome of the project. Analysis of the farmer survey data do not find significant effects of the app on farm labour. All farmers increase their use of labour from the baseline to the endline year, but farmers with the app seem to do so in less extent than farmers in the control group. The farm labour data is used in a book chapter currently in review for the book "Coffee – the glimpse for the future" published by Elsevier.
Output 1.3.1: Innovative platform for systems transfer	App platform system established [1]	he app platform and engines at RTA were tailored to deliver information to coffee farmers in the rtWorks application, incl. new modules on: i) farm description and diary; ii) weather forecasts; iii) Seasonal weather forecasts and associated

		agricultural advisory; iv) fertilizer recommendations based on yield targets; v) a THIRST model - Targeted Irrigation Support Tool – to help farmers assess irrigation needs via self-administered soil moisture assessments and the seasonal forecasts; and vi) shade tree advisory. A scientific article documenting the THIRST model has been published by the journal Frontiers in Sustainable Food Systems. No data was obtained from farmers during the app implementation period. The farmers had the option to contact each other and the RTA team through the app, but no farmers used this option. The expected backend or app usage analytics turned out not to be available due to new GDPR regulations that were implemented after the project start. Users' activities on the app could therefore not be analysed. Three farmers used the daily diary function, but information was not sufficiently detailed to be integrated in the Ag Advisory.
Output 1.3.2: Seasonal yield forecasting system for the private sector	Improvement in yield forecasting skill Private sector implementers [1] (originally: *Number of private sector subscribers*)	Coffee companies in Vietnam showed no commercial interest in yield forecasting, as their current practices worked satisfactorily. Therefore, focus was solely on the farmer facing app. SMS-ECOM, as a subsidiary to one of the largest buyers in the region, started to push their fertilizer and shade tree advice through the app to farmers. SMS is currently investigation how to proceed with the opportunities for service extension offered by the app.
Output 1.3.3: Impact assessment report incl. app usage	App user interface functionality [75 %] Impact assessment report [1]	Data from the farmer endline survey indicates a 45 % use of functions on average by farmers who used the app. Farmers stated on average 75 % satisfaction with user friendliness, relevance and function integration in app. The endline impact assessment with detailed data analyses is annexed to the completion report.
Outcome 1.4: Emissions reductions	CO_2e reductions from fertilizers and shade trees [2520 ton]	Original target was stated as 2.520 tons CO2e reduced in year 3, assuming 1.100 farmers had adopted the fertilizer advisory and 250 had adopted the shade tree advice. In the initial emission reduction calculations, the expected reductions per farmer was 1,33 ton CO2e from fertilizer reductions and 4,2 ton from planting of 80 additional shade trees.

		Due to prolonged app development and covid19 lockdowns, the project was a pilot testing of the app and only targeted at a share of the baseline farmers within the project period. Based on a difference-in-difference analysis coapring farmers with and without the app from the baseline to the endline survey, we found that app-using farmers had a slightly reduced fertilizer use compared to BAU, corresponding to 58 kg per ha and 10,8 to 15,6 ton CO2e in total on their coffee fields. The reduction is an avoided use, as farmers with the app increased their fertilizer use less than farmers in the control group. The range in total emission reductions is a result of two methodologies to estimate emissions from N fertilizers.
Output 1.4.1: Integration of fertilizer (and shade tree) component	Shade tree module in app, based on location and farmers' choice of shade tree services [1] Irrigation and fertiliser recommendation components are integrated in the app [1] (Originally: *Fertiliser component integrated with the yield model*)	The farmer facing app included advisory on shade tree planting and management. However, the endline survey showed no differences in use of shade trees or intercropping between farmers with the app and those without. The fertilizer component consisted of fertilizer recommendations based on yield targets that farmers selected at the start of the season.

2.2 Deviations from the planned outputs and activities

The original project proposal included a **yield forecasting service** to coffee buyers, based on yield modelling of crop management and climate factors. This would enable buyers to better manage their purchase and sales of coffee. However, based on interviews with most major coffee buying companies in Vietnam, there was no commercial interest in improved yield forecasting beyond buyers' current practices of counting flowers and fruits during field officers' regular farm visits and little to no interest to purchase yield forecasting services. It was decided not to move forward with the yield forecasting service and instead focus on the farmer facing agricultural advisory. Activities and outputs related to yield forecasting were not implemented (1.2.2 activity, 1.3.2 indicator and activities, 1.4.1 indicator).

The original proposal to merge data from biotic and abiotic sensing tools with real time farmer management data to create **farmer specific tailored agricultural advisory** could not be carried out. Data from installed weather stations and MimosaTek sensors (soil moisture) were continuously collected in real-time for the first two years after installation. However, we were not able to utilize this data for validation/verification due to the fact that no farmers recorded their coffee practices

(e.g., fertilizer use and irrigation) directly in the app. This type of data was therefore not available to be fed back into the **inbound logistics for model calibration** (1.2.2 activity). Due to the severe travel restrictions enforced during to Covid19 period, the maintenance of sensors also became challenging.

Due to more stringent personal data requirements in mobile application stores, it was not possible to collect and use backend data from farmers' use of the app (1.3.3 activity). Therefore, only survey data was available to **assess usage and functionality of the app**.

A **shade tree advisory component** was added to the app based on a review of shade tree management, current advisory among project partners and data from the baseline survey. The use of shade trees is essential in climate adaptation in coffee. However, the Vietnamese coffee sector is greatly influenced by public policies also in terms of farmers' choice and management of shade trees, which have been mainly limited to intercropping of pepper and fruit trees. Farmers with access to the app and thus the shade tree advisory did not show an increased use of shade trees after one year of app access compared to non-users. This is also expected as shade tree management is a long term strategy by farmers and, in the case of Vietnam, a topic mainly influenced by public policies.

2.3 Achievement of NCF indicators

The table below details the achievement according to the NCF indicators. As described in the endline impact assessment report, part of the MS 4/5 progress reporting, no significant effect of the app on use of coffee labour or household gross income could be detected. A difference-in-difference analysis comparing household gross income among farmers with and without the app from the baseline to the endline season, indicated an increased income development among farmers with the app; however, the effect was not statistically significant.

NCF core indicator	Results (quantitative)		Clarifications/Means of verification
Number of beneficiaries reached	women	57 in farming households 4 staff	56 farmers who downloaded the app and their households, representing 223 household members. Only counting husband and/or wife, plus when other household members were mentioned as app users, e.g., son and niece. SMS staff who were trained in the app content and may use learnings in future farmer training. In addition, close to 100 farmers, who were not part of the baseline survey, participated in workshops and trainings. These are not included in the numbers. Spill-over effects potentially:
	men	58 in farming households 15 staff.	
	total	115 adult farmers 19 staff	

Number of people with increased resilience to climate change	women		57 in farming households	The same 56 farming households, plus any friends and neighbors with whom they share information (not included in the numbers). See also below. Farmers in the training workshops. They were directly impacted during the project. Since then, SMS staff has continued to use the learnings from the project in their farmer training.
	men		58 in farming households	
	total		115 adult farmers	
Number of people with improved livelihoods	women			Potentially the same as above, though unknown to what extent the exposure to improved information on climate and coffee farming have led to improved livelihoods. Analysis of the endline and baseline survey data does not indicate a significant effect on household gross income, though the income of the farmers with the app increase more than the farmers in the control group, corresponding to 5 million VND or around 200 Euro. As this is not significant and it is gross income, it is not possible to conclude that livelihoods have been improved. As a perennial crop, changes in coffee management takes time to materialize into measurable benefits, not least in the case of improved capacity to deal with adverse climatic events. During the time of the app implementation, there were no major climate incidents that affected the sampled farmers. Endline survey data confirms this. However, with access to advisory regarding shade management, irrigation and fertilization, farmers with the app have improved their human capital related to adaptation to adverse climate events.
	men			
	total		Unknown	
New decent jobs created	full-time	women		Due to the pilot nature of the project it is not expected that new jobs have been created as a direct outcome of the project activities. It has not been possible to assess if jobs have been created or not.
		men		
		total	0	
	part-time	women		
		men		
		total	0	
	seaso-nal	women		
		men		
		total	0	

3. CLIMATE CHANGE

The project's aim was to increase climate change mitigation among coffee farmers through reduced use of inorganic fertilizers and increased use of shade trees, as well as improve climate change adaptation through more timely irrigation practices as well as use of mulching and shade tree management. The comparison of baseline and endline survey data showed no effect of app usage on shade tree management, i.e. planting of additional shade trees. Measured in number of non-coffee trees on the largest coffee plot, not counting small fruit trees, the average number of trees per ha was 13,4 among all farmers in the baseline season, while the average had increased to 14,9 in the endline season. In retrospect, this was an ambitious aim giving the important role of public policies on intercropping in coffee, which currently focuses on intercropping pepper and fruit trees in coffee plots.

A difference-in-difference analysis (comparing differences between farmers with the app and without the app between the baseline and endline seasons) showed a minor effect of the app on fertilizer use, corresponding to treated farmers (with the app) using 58 kg/ha inorganic fertilizers less than the control farmers taking into account a number of socio-economic characteristics. The reduced fertilizer application is an avoided use, based on what would be expected if the treated farmers had acted like the control group farmers. Using the standard, average emission rate for production and application of inorganic fertilizer at 2,6 kg CO2e/kg (Cool Farm Tool and Bouwman et al., 2002), the emission reduction of 58 kg inorganic fertilizer per ha corresponds to 0,152 ton CO2e/ ha. Alternatively, the refined IPCC 2019 methodology for direct emissions from field applications of N uses an emission factor of 7,493 kg CO2e/ kg N. Based on the survey data, the average content of N in the inorganic fertilizers used by farmers is 18 %, which means the N reduction is 10,5 kg N per ha, corresponding to direct emission reductions of 0,079 ton CO2e/ ha. Including emissions from the production of the N-fertilizers, transportation and indirect field emissions increases the total emission factor to 21,9 kg CO2e/ kg N, corresponding to reduced emissions of 216,8 kg CO2e/ ha.

If farmers socio-economic characteristics are not considered, the treatment effect is reduced to 1,307 kg fertilizer per ha. Using the IPCC 2019 emission factor from field applications of N only (thus excluding production, transport and indirect emissions), yields a total GHG emission reduction of 1,76 kg CO2e / ha. The 56 treatment farmers have a total coffee area of 71,26 ha, which means the resulting reduced or avoided emissions reach 0,126; 10,8 or 15,6 ton CO2e based on the three methodologies, respectively. The different emission reduction or avoidance results emphasize the importance of methodology, assumptions and system delimitation when estimating climate impacts of a certain activity. The most conservative measure is reported in the project's GHG emission calculations. The most conservative measure is reported in the project's GHG emission calculations.

Interestingly, there are large differences between smaller and larger farmers (relative to the median), with smaller farmers actually increasing their fertilizer use since the

baseline, while larger farmers substantially reduce their fertilizer use. This may be due to farmers needing a certain absolute minimum coffee harvest for coffee farming to be economical viable. On smaller farms and with fertilizer costs not being a limiting factor, focus is on intensive use of inputs to reach this minimum harvest, whereas larger farms benefit from the larger coffee area. The exact pathway for the app effect, seemingly limited to relatively larger farmers, requires longer data series and more focus on how different farmers receive and react to the advisory. The change in fertilizer usage by farmers between the two seasons is influenced by many other factors than app access and usage. The endline coffee season saw a very dry July and June (2021), with many farmers responding with prolonged irrigation as a short-term solution. The price of fertilizer and other inputs increased substantially towards the end of the season, as global supply chains were disrupted during and after Covid19. Without these circumstances, we may have seen even larger use of fertilizers in the endline season and larger differences between the two farmer groups. A longer-term project, with longer panel datasets, would enable a more thorough analysis.

While treated farmers adopted a slightly higher number of adaptation practices than control group farmers, these differences disappeared when we control for other socio-economic characteristics such as age, gender, household size and total land holding. Farmers in the treatment group as well as other farmers, who were not in the baseline but participated in workshops and were introduced to the app, have access to weather and seasonal forecasts as well as general and place specific advisory on e.g. mulching, cover crops, irrigation needs, fertilizer recommendations etc. This may still affect their farming in the seasons following our endline season, as the baseline data shows that having access to mobile internet and thus timely information results in farmer practicing more adaptation strategies and having a higher coffee yield. The results are presented in an articled accepted by the Journal of Agricultural and Resource Economics.

4. DEVELOPMENT IMPACTS AND CROSS-CUTTING ISSUES

In Vietnam, the National Target Programme to Respond to Climate Change (NTP-RCC) was recently drafted to include a larger focus on mitigation, as opposed to just adaptation, and includes a commitment to reduce GHG emissions by 8 % by 2030. In addition to the NTP, the first objective within the Resources and Environment sector of the Sustainable Development strategy of Vietnam, is the Effective and Sustainable use of Land Resource's and Degradation Prevention. A key priority is the introduction of techniques which mitigate the use of fertiliser and chemical substances in agriculture production as well as several decrees and resolutions under the Master Plan which focusses on coffee rejuvenation, water saving technologies and support for training. The app developed in this project aims at both mitigation and adaptation, and in particular on improved fertilizer use and irrigation practices. The app went through several rounds of co-creation between project partners to develop a tailored seasonal climate forecasting system and a set of associated decision support tools for

coffee farmers. The seasonal forecast tool and suite of management solutions may ensure farmers and supporting actors are able to amend practices and adapt systems well in advance, thereby strengthening resilience. Though impacts are not much visibly after the endline survey, the development of the specific app modules can contribute to further development of digital farming tools for extension work and directly for farm management.

Throughout project activities, attention was paid to issue such as gender and social inclusion. Although the sampling strategies of the baseline and endline survey did not target women or ethnic minorities, these surveys included questions that help identify those marginalized groups for analysis. In addition, in a series of midline qualitative interviews with coffee sector actors, questions on equal access to advisory between genders and ethnic groups were included. Most interviewees perceived the access to be equal and mentioned there were special services targeted to women and ethnic minorities.

Digital tools, including mobile applications, are becoming more widespread. Though many of the first experiences have not led to many economically viable and lasting applications in the coffee sector, digitial literacy is building up among all actors. Larger coffee buying companies are increasingly integrating digital tools in their environmental and social governance systems oriented at the farming segment. The app developed in this project is still functioning and third parties have shown interest in the app's modules, and the private partner SMS-ECOM is in discussion to what extent the app's function can be integrated in their existing digital tools.

5. ASSESSMENT OF THE RESULTS AND IMPACTS OF THE PROJECT

5.1 Relevance

The original objectives of the project are still relevant to the Vietnamese coffee sector, both for agricultural advisory service providers such as SMS-ECOM and farmers as end beneficiaries. The purpose of the pilot project was twofold: i) improving agricultural advisory when combined with seasonal weather forecast and ii) implemented using a farmer facing application. Ambitions were to tailor generic agricultural advisory to specific field conditions and to increase its availability as well as farmer outreach at minor costs when compared to traditional onsite field visits from agronomists. Data driven management and digital tools for data registration and analysis and communication is part of the wider agricultural development. Our project succeeded in developing and disseminating an app that is one piece in this development, as well as to obtain experiences for new developments. The individual modules may also be integrated into other digital platforms, such as the seasonal forecasting, as climate information services are becoming more important as the climate changes in the coffee producing areas. As such, the app, its modules and the experiences collected go beyond the limited quantitative results found in the

baseline-endline analysis. All project partners continue to be involved in coffee research in Vietnam, where these experiences are important.

5.2 Effectiveness

The main quantitative expected outcomes in terms of mitigation effects through reduced fertilizer use and tree planting, and adaptation effects through shade tree management and improved irrigation practices, have not been realized. The project had a more pilot-oriented nature than first envisaged. The yield forecasting systems were not prioritized, as there were no commercial interests in these. We successfully developed a farmer facing app that includes i) localized seasonal forecasts, which are better than what existed pre-project, ii) an irrigation needs module based on farmer entries and the seasonal forecasts, and iii) a list of specific adaptation strategies that can help farmers manoeuvre a changing climate. Despite the fact that the mechanism of delivery (the app) was not as successful as originally perceived, the project nonetheless yielded important insights into farmers' perception of climate change, current adaptation practices, as well as use of smartphones, the internet and apps usage. The project aimed to increase resilience of smallholder farmers to climate change by providing climate forecast coupled with advisory to inform their farming decision; as well as promoting more efficient use of inputs to reduce emission. This outcome was indeed realised, however through workshops and co-development rather than through app usage.

Shared value throughout the chain and long term ownership of the dissemination channels was not achieved, mainly as a result of the low usage in smartphone applications. This is reiterated in the survey, where only a smaller share of farmers stated to look for apps that offer seasonal forecast or agriculture advisory. Therefore, despite the enormous gap in delivering climate information services (CIS) to farmers, there is currently very little demand for farmer facing apps as information delivery channel. While many farmers do own smartphones, the better working solutions for CIS in place in Vietnam are based on SMS texts send to smartphones and older mobile phones. This more simple communication platform is apparently still relevant in communicating directly to farmers. Apps, on the other hand, are now commonly used by extension workers among larger organisations and companies, and this is a field our experiences and the specific app modules can contribute to.

5.3 Efficiency

Taking into account the overall budget for a very ambitious project, we have gained new knowledge and developed new tools and CIS services (the THIRST module and seasonal forecasting, the app). We did set out aiming to have larger impacts among farmers than what we experienced. Two aspects had large impacts on the operational efficiency of the project; covid19 and missing expertise in human – computer interface development. We managed covid19 as best as possible, mainly with prolongations of the project and awaiting lifting of restrictions, but it meant that resources, mainly staff time, were not as efficiently used as would have. The missing

expertise should have been anticipated. Lesson learned. Pilot projects of these kinds often necessite some form of public R&D funding, as the risk of limited commercial outcomes are too large for individual private companies. Therefore, we do see our partnership – including private local partners and international research institutions – and the NCF funding mechanisms as the best approach in the context.

5.4 Impact

Direct impacts on fertilizer use, GHG emissions, and shade tree management have been described elsewhere. Additional and higher-level effects of the project include a potential for actors in the Vietnamese coffee sector to harvest the experiences of the project; something that is attainable as all project partners continue to be involved in research and development of the Vietnamese coffee sector. As digital literacy and experiences are building up, our project experiences and the developed app modules can find larger roles in farmer facing CIS and agricultural advisory. We found trust to be important for farmers' perception of useful information sources, with family and friends being perceived better than public sources of information. This needs to be considered in development of apps for CIS purposes, though as smartphone use and agricultural apps become more widespread, it may lead to the needed change in norms related to digital tools. It is important to acknowledge that advisory on mitigation and adaptation strategies cannot use smart communication platforms alone, as many farmers still do not have access to smartphones and good mobile internet connections. Specially, more remote areas, where ethnic minorities may comprise a large part of the population, should also be serviced with other platforms.

5.5 Sustainability

The app continues to be functioning, though partners are not actively pushing for further uptake of the app among coffee farmers currently. Therefore, with no further investments of time and funds, the current app with inbound data logistics will not be continued for long. However, the individual modules can be used in other apps with some adjustment, e.g., as APIs. The THiRST module and the seasonal forecasts are important outputs that can, with few adjustments, be used in other contexts, on different platforms and with different users in mind. The THiRST module is described in detail in a scientific article published in Frontiers in Sustainable Food Systems. SMS-ECOM are looking into integration of app functionalities in their own digital platform. As described earlier, the forecasts will continue to be created for other research projects.

The app developer, RTA, has been contacted by coffee companies with interest in certain modules of the app. As the rtWork app works with a suit of modules targeting both farmers and agricultural companies, there is great flexibility in adding relevant

modules from the current project to existing and new costumers of RTA. However, further development of the agricultural advisory content requies a collaboration with a research institute with the necessary skills. Collaborators could be found among public entities, such as WASI that works with coffee farmers in the Central highlands.

5.6 Coherence

In line with the results from the endline survey, farmers may not consult another application for information services. SMS-ECOM through its network of certified farmers envisages to bundle the provision of information services with the access to other goods and services in order to facilitate their dissemination, adoption and eventually translation into informed decisions for improved farming and post-harvest practices. The project is coherent and compatible with the recent efforts of coffee sectors in general to improve the sustainability of coffee landscapes and progressively reduce the units of resources (water, fertilizer) utilized per unit of coffee produced. This is not only an aim for the Vietnamese coffee sector, but for coffee producing countries in general as major export markets for coffee increasingly value and/or require low impact agricultural production. The experiences of app development flows into two other projects at the University of Copenhagen regarding digital applications in coffee farming in Latin America with variety-yield-climate forecasting in mind, and in Uganda aiming at digital twinning and scenario modelling of coffee agroforestry systems. RTA, as one of the leading Vietnamese companies providing digital services to the agricultural sector, will carry over their experiences from the project into the continued development of their suit of applications based on the rtWork platform and targeted at agriculture. This includes e.g., farmer registration of Good Agricultural Practics for the VietGAP certification.

6. INNOVATION

Indeed, the app was innovative in its potential to improve climate information services to farmers to support their mitigation and adaptation strategies in coffee production given the uncertain climate conditions they are in. The THIRST module and the combination of seasonal forecasts and agricultural advisory, including irrigation needs when combined with the THIRST soil moisture calculations, were innovative and low-cost solutions to coffee farmers in Vietnam. If implemented and communicated to the farmers in the *right way*, the potential benefits to coffee farmers are substantial. The innovativeness was also the challenge. Farmer facing apps have in general been very difficult to upkeep post-project, and we were not able to identify the *right way* in terms of activating farmers' use of the app. We lacked insights into nudging mechanisms and creation of incentives for farmers to integrate the app into their seasonal coffee management. When this is solved at some point, timely and localized agricultural advisory will prove its substantial potential to

improve farming and farmer livelihoods, also in the rural context of coffee producing regions.

7. POTENTIAL FOR SCALING UP AND FOLLOW-UP INVESTMENTS

A substantial scaling up or replication of the app in other contexts requires grant financing until a viable business model can be identified. More realistically, specific modules or functions will be carried on in other projects. Partial replications are planned for in new research projects amongst others in a project in Uganda, financed by DANIDA, that also includes the development of digital tools, though not aimed at farmers but rather at extension services. From the perspective of SMS-ECOM, the outcomes of the project will inform further development of agricultural advisory to farmers. It is still unknown if this entails continuing the use of the app for farmer facing advisory or if learning outcomes are integrated in new solutions. For this activity, SMS-ECOM will not require further external funding or grant financing as we would rather explore the development of in-house solutions to service farmers in our certified network. With RTAs flexible digital platform underlying the rtWork app, relevant modules from the current project can be useful in other versions of the app to existing and new costumers of RTA. In all cases, the use of the seasonal forecasts requires CIAT's involvement. As long as CIAT continues to produce the forecasts for research purposes, the investment is only related to transfer of forecasts to the digital platform. The agricultural advisory depends on a provider of agricultural knowledge, which could be found among research institutes in Vietnam, such as the Western Highlands Agriculture & Forestry Science Institute (WASI). This requires political priority and funding.

8. RISKS

Covid 19 was the main risk for this project. Lockdowns and restrictions on travels in Vietnam delayed fieldwork activities and disrupted normal work processes. This resulted in general delays, extensions of the project, and revisions to milestones.

With project partners dispersed globally with no option to meet physically, we could not carry out events with physical presence of all partners, such as multi-day workshops at essential points in the project. This had been successful in the first part of the project to align, discuss and find consensus on the most effective pathway, but was unfortunately missing in the last 2 years. In response, we carried out regular online meetings and WhatsApp group chats to make up for the lack of physical meetings and presence of project partners in the implementation areas.

The lack of expertise in the project team regarding app user design and user experience likely reduced the app modules' compatibility with farmers' incentives for app usage, perception of information and their decision-making processes. To the

extent possible within the project, we sought advice from an expert in design interaction from Wageningen University, but resources did not allow sufficient involvement of the expert.

Another risk was the restriction of backend data usage by the new data protection regulations. We originally planned to supplement the endline data with data from the backend database that monitors and stores data on users' app usage. However, this was not possible. New data protection regulations came into effect during the course of the app development, which limited the collection of user data for apps downloaded via Google Play or the App Store (as is the case of rtWork). In order to make sure to comply with the regulations, RTA did not collect any data that a user had not specifically granted access rights to within the app. In response to this risk, we used endline survey data to track the experiences of farmers, who installed the app during the midline farm visits.

9. MONITORING AND EVALUATION

During the first part of the project, possible versions of the app pages were presented to coffee farmers during workshops in Dak Lak. This resulted in feedback on use of pictograms and page setup. The project activities and results have mainly been presented to colleagues among the involved partners for immediate feedback. This included a larger group of researchers at CIAT in Hanoi and at the University of Copenhagen. Presentations have either included a general presentation of the project and results, in which case feedback has also been general, or on specific data and results, in which case the feedback has led to improvements to model specification, data management and analysis. More non-scientific presentation have been given to companies, students and the broader public, which has generated interest in the project, but no feedback for improvement in project design, implementation or similar. Scientific papers have received peer reviews for improvements to the individual papers.

10. LESSONS LEARNT

Generally, the project was well planned. However, we have learned several lessons during the project that – if integrated from the start – would have increased likelihood for larger app uptake and effect. The development of apps requires human-computer interface expertise in an extent not foreseen at the start of this project, and therefore the necessary resources were not available to this end. For future projects that develop mobile applications more or less from scratch, it is necessary to include human-computer interface experts who can thoroughly model the personas and decision-making scenarios that the app targets. Thourough collaboration with end users – in this case coffee farmers – and several iterations of field testing are also necessary.

Relatively few farmers installed the app, mainly due to missing or broken phones as stated by farmers. Investing in cheap smartphones to farmers, even as cheap as 15-USD, would have been an interesting and relevant part of the intervention. If farmers are provided with a smartphone, an incentive could be created directly related to data entry. Farmers who choose not to provide data on coffee plot management would pay a small fee for the smartphone (including the app) or turn it back after a trial period. The fee would be waivered for farmers who enter coffee plot management data, who in addition would receive plot specific advisory based on their plot management. This would create a second treatment group, as we may expect them to behave differently than farmers using their own phones and now being offered a new one.

Farmers in the study areas mostly rely on informal information channels such as their own experience as well as friends' and neighbours' experience to define adaptation practices. Building trust in apps for this kind of information and identifying the best incentives for farmers to invest time in an app are seemingly the most important aspects in the development and dissemination of farmer-facing apps.

A further important factor related to dissemination and uptake is to work with and through local ministries and government meteorological services. It would have been constructive to work with institutes such as the Ministry of Agriculture and Rural Development (MARD) and the National Centre for Hydro-Meteorological Forecasting. There is not only substantial trust associated with these institutes, but they also have a very large base of subscribers to their services.

11. OUTREACH

Results have continuously been presented at university courses, at university and public seminars and conferences, and in scientific reports including articles. More than 300 students and course participants have been reached in total, and more than 500 participants have been informed during open seminars at University of Copenhagen, at presentations to organizations and companies, and in scientific conferences. See progress reports for details.

The following scientific theses, articles and book chapter are in publication or being submitted:

Strange, L. B. (2019). The Impact of Ethnicity on Adaptation Capacity to Climate Change. A comparative analysis of coffee production systems in Vietnam's Central Highlands. MSc thesis, MSc program Agricultural Development, University of Copenhagen.

Fuhrman, T. K. (2020). When it gets hot in the Highlands: climate change adaptation behaviours of coffee farmers in the Tay Nguyen region, Viet Nam. MSc thesis, MSc program Sustainable Tropical Forestry, University of Copenhagen.

Beal, C. (2020). Identifying suitable channels to improve the delivery of climate information services to marginalized coffee farmers in Vietnam's Central Highlands. MSc thesis, MSc program Climate Change, Agriculture and Food Security, NUI Galway.

Kahsay, G.A., Turreira-Garcia, N., Bosselmann, A.S. (2023). Mobile Internet Use and Climate Adaptation: Empirical Evidence from Vietnamese Coffee Farmers. Journal of Agricultural and Resource Economics 48(3), 429-447. http://dx.doi.org/10.22004/ag.econ.322849

Nguyen, K.T., Craparo, A.C.W., N., Nguyen, P.M., Turreira-Garcia, T. Talsma, Deniau, A., Bossolasco, L., Le Dang, T., Bosselmann, A.S. (2023). ThIRST: Targeted IRrigation Support Tool for sustainable coffee production. Frontiers in Sustainable Food Systems. https://doi.org/10.3389/fsufs.2023.1267388

Kahsay, G.A., Trifcovic, N. Trust and climate adaption: empirical evidence from Vietnam and Ethiopia. In final preparation and will be submitted to the journal Global Environmental Change.

Turreira-García, N., Craparo, A.C.W., Nguyen, P.M., Deniau, A., Bosselmann, A.S. Co-producing knowledge to adapt Robusta coffee farming to climate change. In final preparation and will be submitted to the journal Science of the Total Environment.

Kahsay, G.A., Bosselmann, A.S., et al. Smartphone applications for coffee farming advisory. In preparation, awaiting target journals.

Koutouleas, A., Bosselmann, A.S., Rahn, E. (2024). Is agroforestry a sustainable management system for future coffee production? In: DaMatta, F.M., Ramalho, J.D.C. (Eds). Coffee – the glimpse for the future. ABR Series, Elsevier.

12. FINANCIAL SUMMARY

Table 1. Project financing per partner

	Financing, EUR						
Expenditures, EUR	NCF	Grantee University of Copenhagen	International Center for Tropical Agriculture	Real-Time Analytics Company Limited	SMS Vietnam	Revenues from the project	Total
Grantee University of Copenhagen	132.346,96	58.124,99					190.471,95
International Center for Tropical Agriculture	248.218,78		154.849,34				403.068,12
Real-Time Analytics Company Limited	51.600,00			82.946,58			134.546,58
SMS Vietnam	0,00				28.928,04		28.928,04
Total	432.165,74	58.124,99	154.849,34	82.946,58	28.928,04	-	757.014,68

13. CONCLUSIONS AND RECOMMENDATIONS

The project has led to many positive outcomes as well as lessons learnt, despite not being successful in leading to substantial changes in GHG emission reductions or facilitating further agroforestry practices among coffee farmers in the Central Highlands. The app has shown how we are able to translate and simplify complex seasonal forecasts into a tool, which bridges the gap between scientific information and practical recommendations. However, the process has also revealed important considerations in app development and dissemination, and allowed us to identify that there may be more efficient ways of disseminating forecasts and related advisory, such as through trusted extension services, local input suppliers, or even television. Early involvement of farmers in co-creation activities is important. Farmers should be involved in the earliest stage – choosing the suitable channels for information delivery. Their participation in all steps of the design process of an app or other vehicles of climate information services will enable the end product to be more useful and suitable to them. Furthermore, expertise on human-computer interfaces is needed from the very beginning of the design process.

Wefocos has made scientific information more actionable for farmers, who can adjust and adapt their management practices driving more sustainable farming and

improved business. As more data and information regarding climate changes and impacts on farming become available from various sources, it is important that this information is made available to the farming community. Our project has shown that it is indeed possible to transform climate datasets and models into easy-to-interpret maps in smart-phone applications coupled with associated agricultural advisory. This development is relevant for digital solutions targeting farmers, agricultural extensionists services or agribusinesses. For better dissemination among farmers in rural areas, and considering that lack of smart phones or broken or lost phones were the main reasons for the limited use of the app, we recommend to provide farmers or farmer group leaders with a cheap smartphone, where the app is pre-installed. This may be contingent on certain performance measures, depending on specific project objectives, and would for many projects be an economic viable option. If farmers are provided with a smartphone, an incentive could be created directly related to data entry. Farmers who choose not to provide data on coffee plot management would pay a small fee for the smartphone (including the app) or turn it back after a trial period. The fee would be waivered for farmers who enter coffee plot management data, who in addition would receive plot specific advisory based on their plot management. This would increase the benefits of app use and start a positive feedback loop, effectively creating the needed incentives.

Going forward, the Wefocos project partners will discuss options for continuation of the seasonal forecast and the different modules of the app. Partners are already engaged in new projects for digital solutions in coffee cultivation and trade, using the experiences from the Wefocos project.

Annex 1 Project completion fact sheet

Project Name:	**Improved Business Through Seasonal Forecasting for Coffee in Vietnam**		
Project no.	NCF-C7-047		
Country:	Vietnam	**Financing:**	
		EUR	**%**
Nordic Partner:	University of Copenhagen	58.124,99	8
Local Partner:	International Center for Tropical Agriculture (today: Alliance Bioversity International – CIAT)	154.849,34	20
Local Partner:	Real-Time Analytics Company Limited	82.946,58	11
Local Partner:	SMS Vietnam	28.928,04	4
	NCF grant disbursed	432.165,74	57
	Total	**757.014,68**	**100.00**
Classification:	Mitigation - Adaptation Combination		
Project cycle:	Project start date: 3.9.2018 Original closing date: 3.3.2021 Actual closing date: 31.8.2022		
Short project description:	The aim of this project is to deliver climate forecasts and support for coffee farmers in Vietnam to enhance economic growth, coffee quality and environmental sustainability. Vietnam is the second largest coffee producer globally; however, climate change impact assessments suggest a reduction of up to 60% of suitable growing area by 2050. The ability to forecast extreme/unusual climate conditions months in advance for farmers to adapt their crop management strategies, is one of the most important developments in environmental sciences of current times. The core of this project is the development of a tailored seasonal climate forecasting system and a set of associated decision support tools for coffee farmers, delivered to farmers via a smart-phone application. The decision support tools will be customised to translate the climate forecasts into managerial options for farmers. The solutions aim not only to enhance the profitability of current farming systems, but also improve their climate change resilience and environmental sustainability. The app has shown how it is possible to translate and simplify complex seasonal forecasts into a tool, which bridges the gap between scientific information and practical recommendations. However, the process has also revealed important considerations in app development and dissemination, and allowed us to identify that there may be more efficient ways of disseminating forecasts and related advisory, such as through trusted extension services, local input suppliers, or even television. The project has made scientific information more actionable for farmers, who can adjust and adapt their management practices driving more sustainable farming and improved business. While the actual emissions reductions from coffee farmers' improved use of inorganic fertilizers were limited after one year of app implementation, several important findings were made regarding farmers' app use, such as app module functionality and user perceptions. This will support a possible development of the app and provide valuable information for future work in this market area on how mobile applications can assist the coffee farming sector.		
Project performance:	**Expected Outcomes and Outputs [Incl. revisions to Milestones]**	**Achieved**	**End-of-project status**
	Outcome 1.1: Five customised adaptation solutions that incorporate existing knowledge and practices	Yes	Several adaption advisory to each agro-ecol region included in the project.
	Output 1.1.1: A database of farmer's needs; a database of stakeholder needs.	yes	
	Output 1.1.1: 200 farmers participating in the knowledge workshop	Partial	Approx. 100 farmers were engaged in knowledge sharing
	Output 1.1.2: Baseline database	yes	
	Output 1.1.3: Novel site-specific recommendations and adaptation options	Yes	As Outcome 1.1
	Outcome 1.2: 200 baseline farmers introduced to the app. (Originally phased as *200 users subscribed to the forecasting system)* 100 farmers using the app and adopting recommendations (originally: *Adopters of recommendations*) 500 female farmers using the app services (Originally: *1000 females subscribed to the forecasting system*) 500 ssers per focus area/region. (Originally: *500 subscribers*)	Partial	161 farmers introduced to the app. 56 farmers successfully installed the app and logged in to the system. An additional 85 farmers, not part of the baseline, were introduced to the app through workshops.

	2000 users of the forecasting system. (Originally: *2000 users subscribed to the climate forecasting system*)		The endline survey showed 10 active app users in Lam Dong and 12 active users in Dak Lak. 14 farmers specifically stated to use the forecasts and related agricultural advisory.
	Output 1.2.1: Reduction in seasonal forecast error	Yes	Forescast hindcast skill improved from 60 – 80% of earlier regional climate models to 80-90 %.
	Output 1.2.2: 50 farmers implementing the adaptation solutions	Partial	See below.
	Output 1.2.2: 200 farmers using the app and adopting recommendations, half of them women farmers, and found across project areas	Partial	22 farmers self-reported to actively use the app; 10 in Lam Dong and 12 in Dak Lak; One-third of users were women.
	Output 1.3.1: Platform system established	Yes	Based on Real Time Analytics existing platform
	Output 1.3.2: One private sector backer. (originally: *Number of private sector subscribers*)	Partial	SMS-ECOM, as a subsidiary to one of the largest buyers in the region, started to push their fertilizer and shade tree advice through the app to farmers.
	Output 1.4.1: Shade tree module integrated in the app. (originally: *Fertiliser component integrated with the yield Model*)	Yes	Shade tree module was integrated in the app, and the fertilizer advisory given based on yield target.
	Outcome 1.3: New jobs created, for women, and seasonal jobs		No target set. Not expected as direct outcome of the project.
	Output 1.3.3: 75 % app user interface functionality	Partial	45 % use of functions on average by users; and 75 % satisfaction with user friendliness, relevance and function integration in app.
	Output 1.3.3: Impact assessment report	Yes	
	Outcome 1.4: 2520 ton CO23 reduction per year from fertilizers and shade trees	No	No effect on farmers management of shade trees were detected. Very minor effect of directly reduced use of fertilizer, though larger effect when measuring avoided use.
Climate change outcomes and impacts:	The climate change outcome assessment is based on a comparison of two groups of farmers and the use of shade trees and inorganic fertilizers after one full coffee season, where one group of farmers had access to the app while the other group did not. The comparison showed no effect of app usage on shade tree management, i.e. planting of additional shade trees. In retrospect, this was an ambitious aim giving the important role of public policies on intercropping in coffee, which currently focuses on intercropping pepper and fruit trees in coffee plots. A difference-in-difference analysis between the two groups showed a minor effect of the app on fertilizer use, corresponding to those farmers with the app using 58 kg/ha inorganic fertilizers less than the control farmers taking into account a number of socio-economic characteristics. The reduced fertilizer application is an avoided use, based on what would be expected if the treated farmers had acted like the control group farmers. If farmers socio-economic characteristics are not considered, the treatment effect is reduced to 1,307 kg fertilizer per ha. Using the IPCC 2019 emission factor from field applications of N only, yields a total GHG emission reduction of 1,76 kg CO2e / ha. The 56		

	treatment farmers have a total coffee area of 71,26 ha, which means the resulting reduced or avoided emissions reach 0,126; 10,8 or 15,6 ton CO2e based on the three methodologies, respectively. The most conservative measure is reported in the project's GHG emission calculations. While treated farmers adopted a slightly higher number of adaptation practices than control group farmers, these differences disappeared when we control for other socio-economic characteristics such as age, gender, household size and total land holding. Farmers in the treatment group as well as other farmers, who were not in the baseline but participated in workshops and were introduced to the app, have access to weather and seasonal forecasts as well as general and place specific advisory on e.g. mulching, cover crops, irrigation needs, fertilizer recommendations etc. This may still affect their farming in the seasons following our endline season, as the baseline data shows that having access to mobile internet and thus timely information results in farmer practicing more adaptation strategies and having a higher coffee yield.
Development outcomes and impacts:	A key priority in Vietnam's National Target Programme to Respond to Climate Change (NTP-RCC) is the introduction of techniques which mitigate the use of fertiliser and chemical substances in agriculture, and several decrees and resolutions under the Master Plan focusses on coffee rejuvenation, water saving technologies and support for training. The app developed in this project aims at both mitigation and adaptation, and in particular on improved fertilizer use and irrigation practices. The app went through several rounds of co-creation between project partners to develop a tailored seasonal climate forecasting system and a set of associated decision support tools for coffee farmers. The seasonal forecast tool and suite of management solutions may ensure farmers and supporting actors are able to amend practices and adapt systems well in advance, thereby strengthening resilience. Though impacts are not much visibly after the endline survey, the development of the specific app modules can contribute to further development of digital farming tools for extension work and directly for farm management. Digital tools, including mobile applications, are becoming more widespread and though many of the first experiences have not led to many economic viable and lasting applications in the coffee sector, digitial literacy is building up among all actors. Larger coffee buying companies are increasingly integrating digital tools in their environmental and social governance systems oriented at the farming segment. The app developed in this project is still functioning and third parties have shown interest in the app's modules, which can be integrated in their existing digital tools.
NCF core indicators	

NCF core indicator	**Results (quantitative)**		**Clarifications/Means of verification**
Number of beneficiaries reached	women	57 in farming households 4 SMS staff	56 farmers who downloaded the app and their households, representing 223 household members. Only counting husband and/or wife, plus when other household members were mentioned as app users, e.g., son and niece. SMS staff (see MS progress, 181 + 85 farmers not in baseline sample but participating in Workshops and SMS meetings) Farmers in the training workshops. Spill-over effects, potentially.
	men	58 in farming households 15 SMS staff	
	total	56 farming households 19 SMS staff	
Number of people with increased resilience to climate change	women	57 in farming households	The same 56 farming households, plus any friends and neighbors with whom they share information. See also below. Farmers in the training workshops. Numbers not included.
	men	58 in farming households	
	total	Minimum 56 farming households	

	Number of people with improved livelihoods	women			Potentially the same as above, though unknown to what extent the exposure to improved information on climate and coffee farming have led to improved livelihoods. Analysis of the endline and baseline survey data does not indicate a significant effect on household gross income, though the income of the farmers with the app increases more than the farmers in the control group, corresponding to 5 million VND or around 200 Euro. As this is not significant and it is gross income, it is not possible to conclude that livelihoods have been improved. As a perennial crop, changes in coffee management take time to materialize into measurable benefits, not least in the case of improved capacity to deal with adverse climatic events. During the time of the app implementation, there were no major climate incidents that affected the sampled farmers. Endline survey data confirms this. However, with access to advisory regarding shade management, irrigation and fertilization, farmers with the app have improved their human capital related to adaptation to adverse climate events.
		men			
		total	Unknown		
	New decent jobs created	full-time			Due to the pilot nature of the project it is not expected that new jobs have been created as a direct outcome of the project activities. It has not been possible to assess if jobs have been created or not.
			0		
		part-time			
			0		
		seasonal			
			0		

Annex 2 Results Framework

Expected outcomes and outputs	**Indicators [and original targets]:**	**Achievement of outcomes and outputs:**
Outcome 1.1: Farmers' knowledge integration	Farmers knowledge Customised adaptation solutions [5]	Described below in output 1.1.1 to 1.1.3.
Output 1.1.1: Knowledge Database	Database of farmers' needs [1] - Gender specific needs Database of stakeholder needs [1] Number of (female) farmers participating in knowledge workshops [200 (100)]	A pilot survey of 76 coffee farmers resulted in a good understanding of farmers' needs and their context. A full baseline survey with 400 farmers, using rtWorks Survey platform, resulted in a large database with detailed information on all aspects of coffee farming, climate shocks and adaptation, access to information, livelihoods strategies, and farmer typology, incl. gender aspects as female and male farmers were intereviewed in each household. A scientific article is published in the Journal of Agricultural and Resource Economics. During several rounds, workshops were carried out with close to 100 farmers (around half female farmers), lead farmers and agricultural technicians. Information was obtained in order to develop the format and design of the app for dissemination of Ag advisory and seasonal forecasts. An assessment was carried out of existing mobile applications to identify existing solutions on the market and gaps in climate services. Interviews with 11 coffee buyers/roasters helped to identify stakeholder needs in terms of yield forecasting. It turned out not to be of interest to the coffee buyers, who are already doing rough yield estimates based on flower/fruit counting during the farm visits. Therefore, it was not a viable venue to continue the yield forecasting modelling as part of the commercial services. A report and database of farmer and stakeholder needs were part of the MS1 progress report.
Output 1.1.2: Farmer baseline database	Baseline database [1]	Described above. The database is stored as an Excel file and is still being used for specific studies and data analysis. A farmer database report was part of the MS2 progress report.
Output 1.1.3: Recommendations	Set of novel site-specific recommendations and adaptation options [5]	Based on the baseline survey, the workshops with farmers and extension officers, and on a literature review, an extensive list of recommendations and

and adaptation options		adaptation options were described and subsequently made specific to the three main eco-agricultural types within the research area. Subsequently, the adaptation options [>10] were added to the mobile application. A report document and describing the adaptation options was part of the MS2 progress reporting. A scientific manuscript regarding site specific climate change adaptation strategies based on survey and workshop data is being developed.
Outcome 1.2: Better preparedness of smallholder farmers to climate change	Baseline farmers introduced to the app [200]. (originally phased as *subscribers to forecasting system*) Farmers' use of app and adoption of recommendations [100] (originally: *Adopters of recommendations*) Female farmers using the app services [500] (Originally: *females subscribed to the forecasting system [1000]*) Users per focus area/region [500] (originally: *subscribers*) Users of the forecasting system [2000] (originally: *users subscribed to the climate forecasting system*)	181 farmers from the baseline survey were randomly selected to receive the app. We succeeded to contact 161 farmers via farm visits and telephone calls. Many farmers did not have a phone, their phone was broken, or they had left the area or were no longer farming coffee. The remaining farmers received oral and/or written instructions on how to download the app. 56 farmers successfully installed the app and logged in to the system. An additional 85 farmers, not part of the baseline, were introduced to the app through workshops. No data exist on their use of the app. 22 farmers self-report to have actively used the different modules in the app, including the adaptation solutions. Analysis of the endline data shows no impact of app use on the number of adaptation measures implemented. However, app users on average had a lower use of fertilizer than the control group. While the control group increased fertilizer use in the endline season, the app users slightly decreased their use on average when taking into account the expected fertilizer use based on coffee area and the endline season was a bulk coffee year (highly productive). The endline survey showed 10 active app users in Lam Dong and 12 active users in Dak Lak. 14 farmers specifically stated to use the forecasts and related agricultural advisory. Also see below.
Output 1.2.1: Accurate & reliable seasonal climate forecasting system	Reduction in seasonal forecast error [30 %]	Empirical weather data was complemented with several historical climate datasets, and the combined data was used to develop seasonal weather forecast models. The hindcast skill improved from 60 – 80% of earlier regional climate models to 80-90 %. The was verified with USQ /

		DeRisk information that compared our model to previous models.
Output 1.2.2: Set of associated decision support tools for farmers	Farmers implementing the adaptation solutions [50]	56 farmers installed the app. 22 farmers stated in the endline survey to have actively used (beyond reading content) the app and its different functions. More may have read content, such as fertilizer application amounts as indicated by the lower use of fertilizer among app users. One third of the farmers using the app (22) stated that it was either shared use of the app between husband and wife or the wife using the app. Additional farmers, outside the group of baseline farmers, may have adopted recommendations. This is not recorded.
Outcome 1.3: Shared value throughout the chain and long term ownership	New jobs created, including seasonal, also for women	With the nature of the project being a trial of the forecasting system and agricultural advisory via a farmer facing mobile application, it is not expected that new jobs have been created in the Vietnamese coffee sector or supporting sector directly as an outcome of the project. Analysis of the farmer survey data do not find significant effects of the app on farm labour. All farmers increase their use of labour from the baseline to the endline year, but farmers with the app seem to do so in less extent than farmers in the control group. The farm labour data is used in a book chapter currently in review for the book "Coffee – the glimpse for the future" published by Elsevier.
Output 1.3.1: Innovative platform for systems transfer	App platform system established [1]	he app platform and engines at RTA were tailored to deliver information to coffee farmers in the rtWorks application, incl. new modules on: i) farm description and diary; ii) weather forecasts; iii) Seasonal weather forecasts and associated agricultural advisory; iv) fertilizer recommendations based on yield targets; v) a THIRST model - Targeted Irrigation Support Tool – to help farmers assess irrigation needs via self-administered soil moisture assessments and the seasonal forecasts; and vi) shade tree advisory. A scientific article documenting the THIRST model has been published by the journal Frontiers in Sustainable Food Systems. No data was obtained from farmers during the app implementation period. The farmers had the option to contact each other and the RTA team through the app, but no farmers used this option.

		The expected backend or app usage analytics turned out not to be available due to new GDPR regulations that were implemented after the project start. Users' activities on the app could therefore not be analysed. Three farmers used the daily diary function, but information was not sufficiently detailed to be integrated in the Ag Advisory.
Output 1.3.2: Seasonal yield forecasting system for the private sector	Improvement in yield forecasting skill Private sector implementers [1] (originally: *Number of private sector subscribers*)	Coffee companies in Vietnam showed no commercial interest in yield forecasting, as their current practices worked satisfactorily. Therefore, focus was solely on the farmer facing app. SMS-ECOM, as a subsidiary to one of the largest buyers in the region, started to push their fertilizer and shade tree advice through the app to farmers. SMS is currently investigation how to proceed with the opportunities for service extension offered by the app.
Output 1.3.3: Impact assessment report incl. app usage	App user interface functionality [75 %] Impact assessment report [1]	Data from the farmer endline survey indicates a 45 % use of functions on average by farmers who used the app. Farmers stated on average 75 % satisfaction with user friendliness, relevance and function integration in app. The endline impact assessment with detailed data analyses is annexed to the completion report.
Outcome 1.4: Emissions reductions	CO_2e reductions from fertilizers and shade trees [2520 ton]	Original target was stated as 2.520 tons CO2e reduced in year 3, assuming 1.100 farmers had adopted the fertilizer advisory and 250 had adopted the shade tree advice. In the initial emission reduction calculations, the expected reductions per farmer was 1,33 ton CO2e from fertilizer reductions and 4,2 ton from planting of 80 additional shade trees. Due to prolonged app development and covid19 lockdowns, the project was a pilot testing of the app and only targeted at a share of the baseline farmers within the project period. Based on a difference-in-difference analysis coapring farmers with and without the app from the baseline to the endline survey, we found that app-using farmers had a slightly reduced fertilizer use compared to BAU, corresponding to 58 kg per ha and 10,8 to 15,6 ton CO2e in total on their coffee fields. The reduction is an avoided use, as farmers with the app increased their fertilizer use less than farmers in the control gropu. The range in total emission

		reductions is a result of two methodologies to estimate emissions from N fertilizers.
Output 1.4.1: Integration of fertilizer (and shade tree) component	Shade tree module in app, based on location and farmers' choice of shade tree services [1] Irrigation and fertiliser recommendation components are integrated in the app [1] (Originally: *Fertiliser component integrated with the yield model*)	The farmer facing app included advisory on shade tree planting and management. However, the endline survey showed no differences in use of shade trees or intercropping between farmers with the app and those without. The fertilizer component consisted of fertilizer recommendations based on yield targets that farmers selected at the start of the season.

Annex 3 Pictures

Photos include all photos from the progress reports. Due to file size, photos are annexed to the completion report.

Annex 4 Other supplementary deliverables/documentation/links

Three MSc theses are annexed to the completion report:

Strange, L. B. (2019). The Impact of Ethnicity on Adaptation Capacity to Climate Change. A comparative analysis of coffee production systems in Vietnam's Central Highlands. MSc thesis, MSc program Agricultural Development, University of Copenhagen.

Fuhrman, T. K. (2020). When it gets hot in the Highlands: climate change adaptation behaviours of coffee farmers in the Tay Nguyen region, Viet Nam. MSc thesis, MSc program Sustainable Tropical Forestry, University of Copenhagen.

Beal, C. (2020). Identifying suitable channels to improve the delivery of climate information services to marginalized coffee farmers in Vietnam's Central Highlands. MSc thesis, MSc program Climate Change, Agriculture and Food Security, NUI Galway.

Datasets will be made publicly available in data repositories once the planned analyses have been finalized. Please write to ab@ifro.ku.dk for requests regarding the datasets.

Annex 5 Impact story

Robusta coffee farming in the Central Highlands in Vietnam, as well as in many other coffee production regions, are influenced by a lack of localized agricultural advisory, not least related to mitigation and adaptation practices. In some places, the lack of advisory services lead to low yields. In other places, as in Vietnam, the lack of advisory

leads to excessive use of inorganic fertilizers and unregulated irrigation with adverse impacts on the local environment. With climate change already badly affecting coffee producing regions, there is a need for improve climate information services and agricultural advisory.

Addressing a gap in advisory, seasonal forecasts are often perceived as complex scientific information and hard to interpret by various levels of users. Although there was low adoption of the app and the effect on fertilizer reduction as the main mitigation practices was minor, the project proved that merging scientific outputs with agronomic advisory and farmer knowledge in a co-developed process can yield useful information. This will provide valuable insights for future work in this market area on how technology and information delivery can assist in the farming sector.

The app has shown how we are able to translate and simplify complex seasonal forecasts into a tool which bridges the gap between scientific information and practical recommendations. Nevertheless, this process how allowed us to identify that there may be more efficient ways of disseminating this information, such as through extension services, local input suppliers, or television. Wefocos has made scientific information more actionable for farmers who can adjust and adapt their management practices driving more sustainable farming and improved business.