



# FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative

## Novel Metrics to Support Research, Programming, and Policy in Agriculture, and Nutrition and Health : Findings from India, Nepal and Ghana

### Webinar Transcript

Yaritza Rodriguez

Good morning, afternoon, evening. Thank you for joining today's webinar to learn more about Novel Metrics to Support Research, Programming, and Policy in Agriculture, and Nutrition and Health with Findings from India, Nepal and Ghana. My name is Yaritza Rodriguez, and I'm a Project Coordinator at USAID Advancing Nutrition, and I will be your MC today. I will begin this webinar by going over some housekeeping items. So, I would like to direct all attendees to a few functions on the Zoom call. Please make use of the chat box again on the right side of the window to introduce yourselves. Let us know where you're joining from and share your thoughts and comments during today's webinar by sending a message to "All panelists and attendees".

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At the bottom of your screen, you should see a chat icon and a Q&A icon. Please use the chat feature to engage in relevant conversation with other attendees. If you have a question for one of the panelists, please use the Q&A feature. Panelists will respond to questions and the Q&A as they are able. We have allotted also 20 minutes at the end of this webinar for questions and answers, at which point the panelists will respond to any remaining questions from the audience. If you're experiencing technical difficulties, send a message in the chat to "All panelists" so that our technical support staff can work with you to help resolve any technical issues. Nate Conway from Tufts IT is our IT support today, so please reach out to him by private message if you do have any technical issues.

This webinar is being recorded and will be made available on the Innovation Lab for Nutrition and USAID Advancing Nutrition websites. You can also register for upcoming webinars and our previous recordings and slide decks on our website.

Our moderator for today will be Grace Namirembe, data analyst for the US Government's Feed the Future Innovation Lab for Nutrition. But before heading off to our moderator, I would like to introduce the Director of the Innovation Lab for Nutrition, Professor Patrick Webb. Professor Webb is the [Alexander Mc Farland Professor] of Nutrition at the Freeman School of Nutrition Science and Policy, and the principal investigator of USAID's Food Aid Quality Review Project. Until 2005, Pr. Webb was the Chief of nutrition at the United Nations World Food Program. He has served on numerous task forces and global advisory panels, and is currently the senior advisor to the High Level Global Panel on Agriculture and Food Systems for Nutrition. With that, let me ask Dr. Patrick Webb to take over and provide us with a brief introduction to the Nutrition Innovation Lab. Dr. Webb, over to you.

## Patrick Webb

Thank you Yaritza. We're going to have to cut that bio short, but I appreciate it. Thank you for the introduction. Hello everyone, great to have you join this 7<sup>th</sup> or 8<sup>th</sup>, I believe, webinar on this particular series, hosted jointly in some cases like this case, with Advancing Nutrition that's led by the Feed the Future Nutrition Innovation Lab. We're very happy to be presenting some interesting *novel* findings today. Some webinars are about new science and new findings from research. This one is more about exploring new ways of measuring things, better ways of understanding the metrics that we need to use. You're probably familiar with the women's empowerment in agriculture index, the food insecurity access score, it's really in that space, trying to find innovative ways to measure problems. Very briefly, broad background. This fits into work that has been going on for almost a decade now by the Nutrition Innovation Lab in a range of different countries, deep dives, deep field-level research in countries like Nepal, Uganda, Mozambique, Bangladesh, and so on. But additional work, some of which we'll hear about today, that has explored windows of opportunity where we could link up with researchers from other countries, other situations like the University of Reading for work in Ghana, and India and beyond. So the map you have here is just a snapshot of some of the kinds of activities and the types of places in which we've been working.

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It's a huge global partnership to approach the range of topics that we have been addressing in something as complex as nutrition. So we absolutely recognize all the global, national and local partners with whom... without whom we could not have done this work. Every one of them has been a stellar player in the activities of the Nutrition Innovation Lab.

Next slide... So and of course... we'd miss not to acknowledge all the government partners, USAID, but also beyond USAID, including NASA, which is not on this group.

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So, for this activity, we've had a range of important PIs, co-PIs, and local partners who are listed here. We'll let the speakers go more fully into those.

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So, it's great, we're really happy to be hearing about two particular types of innovative measurement approaches. And the session is going to be moderated by Grace Namirembe who hails from Uganda. She got her MPH from Boston University, joined the Innovation Lab I think at the end of 2014, and we've been really glad to have her as a data analyst with us since then.

So over to you Grace to moderate this interesting panel.

## Grace Namirembe

Thank you Patrick. So now I want to introduce the panelists. We will start with Dr. Robin Shrestha. Dr. Robin is the principal project manager for the ... sorry the regional project manager for the US government's Feed the Future Innovation Lab for Nutrition. He received his Master in Science degree in Policy and Applied Nutrition at the Friedman School of Nutrition Science and Policy at Tufts University. He has a degree in medicine with 8 years of clinical experience in other settings in Nepal. He currently oversees and supports Nutrition Innovation Lab's research and capacity building activities in Asia and

Africa. Then, we'll have Dr. Giacomo Zanello. He is the Associate Professor of Food Economics and Health at the University of Reading in the UK. He is also an [LSE] fellow. Previously as research fellow at the London School of Hygiene and Tropical Medicine. Dr. Zanello supported the work of a global panel on agriculture and food systems for nutrition in his commitment to tackling global challenges on food and nutrition security. From 2012-2015, he was a research officer at Oxford University Department of International Development. Then, we'll have Dr. Lichen Liang who is the data analyst for US Government's Feed the Future Innovation Lab for Nutrition. Dr. Liang provides statistical support for projects in Uganda, Nepal and Mozambique. His research interests are food systems, linkage between agriculture and nutrition, and food insecurity. He specializes in machine learning and is interested in applying new statistical methods to nutrition problems.

So, we will start with Robin, and he will be presenting, and Lichen will be available for questions related to health and nutrition. Robin, over to you,

## Robin Shrestha

Thank you Patrick and Grace. Good morning, afternoon and evening. It's an honor to be here and represent the Nutrition Innovation Lab. As outlined in the webinar... in the slides here, my presentation for the webinar today is on the use of novel data direct from mobile phones to describe the food security situation in Uganda and Nepal. And following my presentation, our second panelist, Dr. Giacomo Zanello will be presenting on the use of novel technology to capture data on energy expenditure, dietary intake and nutrition in rural livelihoods.

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So, this work is jointly being led by Drs. Patrick Webb, Dr. Lichen and Shibani Ghosh, who are also part of this panel today. The content and results used in this presentation are unpublished and this work is currently under internal review.

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So, digital technologies, as we are all aware, have become a part of modern life. And this is even more so true in the case of mobile phones that continue to expand its global reach in the developed as well as in the developing economies. This chart from the 2017 Deloitte's global mobile consumer trends report shows the extent of the global reach with high penetration rates around the mid-80s to 90 percent, both for any mobile phone and Smart phones ownerships. And what is interesting and worth noting is the surge in the last two decades in the mobile phone and its subscription rates in the developing countries, narrowing the gaps in the mobile phone ownerships, which has presented with enormous opportunities for better linkages of information and communication between the developed and the developing economies.

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Mobile phone technologies have raised faster, especially in the lower income countries than any other digital technologies like telephone, broad band Internet, and/or television. This figure is from the 2016 World Development Report that illustrates the significant spread and increase in the ownership of mobile phones in the developing countries in the last two decades, where more households have had access to mobile phones than to electricity, sanitation and education. The line graph highlighted by the arrow here shows that in early 2000 only about 4 per cent of people living in low and middle income countries had access to mobile phones. And that number significantly rose to mid-90 per cent by 2015.

The advent of smart phone access and other value added services such as mobile money and mobile internet has further revolutionized the way we communicate, access to information, and make economic benefits. And this is true for all households as well. This improvement in physical access can be attributed to some key supply-side factors, such as the liberalization in the telecommunication sector, low infrastructure and fixed costs to set up mobile cell phone towers and competitive rates from telecom companies. This in turn... with all households increasingly viewing mobile phones as a necessity than just as a luxury item have made mobile phones cheaper and dramatically increased its affordability and accessibility. In other words, the digital divide in terms of physical access to mobile phones is being bridged very rapidly. However, the low level of disposable income is still a basic constraint to all mobile devices in rural households, such as in Nepal. In addition, the disparity in its uptake and uses exists largely due to socio-economic factors such as age, gender, education and location. And with the growth of Smart phones and mobile internet, and even some other value added services such as mobile money, other dimensions of digital divide should not be forgotten, in terms of digital literacy and usage, they still persist and may have increased for some rural populations.

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To further illustrate the digital transformation in LMIC, I've used this figure as an example from the 2018 Sharecast Initiative Nepal to show the status of digital inclusion and trends of ownership of digital devices in Nepal, which is highlighted in the diagram for mobile phones as the highest commonly used technology in Nepal in all seven provinces. The data are not shown here, but the 2016 Nepal Demographic Health Survey also reported similar widespread ownership of mobile phones, both by gender and by location.

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So as the physical access of mobile phones use become more widespread, data on ownership and usage offer a new source of information relating to household demographics and spending choices. Mobile phones generate an extensive amount of mobile usage data, with a level of granularity and precision that might be difficult to achieve using other data sources. And we're already witnessing a growing use of this data by researchers and development professionals who are here today in evaluation and assessment purposes for wealth and poverty mapping, for real time monitoring, and feedback for targeted disaster reliefs, and for future prediction of disease outbreaks.

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Before diving in how mobile phone data can help capture food insecurity, I'd like to highlight some of the key challenges in measurement of food insecurity. First, conceptualizations of food security are evolving and so are the metrics to measure it. Depending on what component of food security you intend to measure, each of the metrics can differ, and each have their own strengths and limitations. This can be a blessing but also a challenge when trying to choose an appropriate measurement. Second, measuring food security is complex. The assessments of food security or insecurity are mostly experience-based, and so these measures rely on social culture and personal values of insecurity. These may not necessarily resemble with other measures of insecurity itself. On the other hand, one individual's perception of food insecurity may not necessarily represent the experience of all household members. And the data quality due to response and sometimes recall biases pose a challenge to the overall quality of data collected. And finally, opportunizing the assessments requires large scale, rich, and good quality data, which can be expensive and time-consuming. The data can be difficult in areas where access is

limited or restricted. And most of the time the data are cross-sectional and may lack temporal frequency to capture the true food insecurity status.

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Given these challenges, data from mobile phones offer a relatively new source of information to monitor food security for a quick response in high-risk populations. Mobile data can aid in real-time monitoring of food security and can be linked at the country, communities, and even at the household level. The use of anonymized data records from mobile service companies may be cheaper in comparison to the traditional methods of data collection. And having these proxy indicators can complement the quality of high-level surveys and face to face household interviews. It is also worth highlighting that some amount of this work using mobile phone technology has been taking place. And I just want to cite one example of the mobile vulnerability analysis and mapping process that performs continuous food security monitoring using mobile voice call data collection.

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So there are few hypothetical pathways by which mobile phone use may be a viable proxy indicator for household or community food security mapping. And I would just like to highlight three of these pathways. First, there is a literature that documents input incomes and social cohesion and social networks associated with the adoption of mobile phones and input access to information and services. Second, the growing use of mobile phones across even in the remoter areas help increase market engagement for small holders in those areas. And third, food insecurity is associated not only with low income and lack of food availability, but are also driven by physical, social, and information isolation. So the presence or absence of mobile phones reflects the level of potential interactions the users can have, or may have, with the wider world. And this makes mobile phones a strong proxy indicator of security, in relation to food and nutrition. This is further supported by some of the evidence that has been generated previously, that are successfully used in mobile phones to predict socio-economic status at the national level as shown by Blumenstock et al. in Rwanda, where they mapped individuals' mobile phone metadata to individual phone subscribers. Similarly, Gutierrez et al. in their study from Cote d'Ivoire used mobile phone call data records and airtime purchases as proxies for household's wealth, and Decuyper et al. linked mobile phone data to conditions of food security at household level as a proxy indicator for poverty and food consumption. They did this by aggregating mobile phone activity at a scale of 10,000-50,000 inhabitants, and they found high correlations between mobile phone data indicators and food security variables, such as expenditure on food or vegetable consumption.

So the potential exists for mobile phone data to contribute to food insecurity indicators, but there remains a need to test and validate approaches and demonstrate feasibility in real world settings.

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And as a response to that need, our analysis seeks to assess the potential of using mobile phone data, especially on all essential expenditures to build a proxy indicator of quality level food insecurity. One thing I'd like to clarify is that our objective is not to explain food security through this analysis or the causality for that matter, but rather to identify good proxy indicators that can help us measure the distribution and severity of food insecurity. And so for this purpose, we utilize data from the multi-year report Policy and Science for Health, Agriculture and Nutrition survey, in short the PoSHAN survey, implemented by our partners at John Hopkins, that was originally designed to map out pathways through which agriculture may improve maternal and child health and nutrition. This annual survey was implemented over a period of four years between 2013 to 2016 in 21 districts, across three agro-ecological regions, the mountains, hills and the Terai. The study used a systematic random sampling to

select 21 village development committees, known as VDCs, in which three wards from each village were visited. Therefore a total of 63 wards were visited at each time point. And all eligible households with children under the age of 16 months were included in the study. The aggregated data set used for this analysis has 215 ward-level observations that incorporate about 100 households per ward. The massive earthquake in 2015 prevented the data collection from all 63 wards, and therefore we really had a truncated sample of 24... 27 wards sorry for the panel tree. And so we used an unbalanced panel where 27 wards were followed-up in all 4 panels, 35 wards followed in the 3 panels, and one ward was followed up across 2 panels. Due to the nature of the survey sampling design, repeated measures of ward-level food insecurity measures were nested within individual wards, which were then distributed in the VDCs.

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Since the purpose here is to estimate the community-level food insecurity, we used a ward as a committee as it was large enough to develop community-level indicators, but small enough to have sufficient samples for the analysis. Using two household-level mobile phone variables, two community-level mobile phone variables were constructed. The first one is the average number of mobile phones owned by the households within the community, and the second is the average monthly mobile phone expenditure in the form of top-ups and airtime purchases of all households in that community. For the food security variables, the PoSHAN survey used a validated household food insecurity access scale, also known as HFIAS, that measures households recorded behaviors and perceptions of food insecurity through a set of nine questions. And by using the HFIAS at household level we aggregated two community-level indicators to measure community food insecurity. The first one is the HFIAS aggregated at the community level, and the second one is the prevalence of household food insecurity within the community. That's for the analytical strategy. We first calculated the first differences between the survey rounds to document periodic changes in average phone ownership and expenditure alongside with the fluctuations in the food insecurity to be able to capture the empirical relationship between mobile phone indicators and food insecurity. We also built an operative model using multi-level modelling to estimate community food insecurity, using phone variables. We performed repeated cross-validation at the VDC level to further characterize the model and its performance in real world settings, and simulated the model in the wards of the VDCs not included in the sample data. And finally we ran a cross validation stratified by survey rounds where data from panel 1 to 3 were reserved for training and tested the model using panel 4 data. This was done to simulate the case where we wanted to know the current food insecurity status of a community but originally not having food insecurity measures... sorry... What we did was we wanted to simulate a case where we wanted to know the current food insecurity status of the community but only had food insecurity measures from the past few years.

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So as for the results, the plot presented here shows the annual trends in the two mobile phone ownerships and expenditure variables and food security variables. In the X axis, we have the panel years, and in the Y axis, we have the average scores. So the top two plots show the annual trends of the two food insecurity variables across 4 panels, while the bottom two plots show the trends for the phone variables across the panel. The two food security variables increased significantly across the survey years, and similarly the mobile phone ownerships increased over the survey years as well, and the differences in the mean values were statistically significant at 0.01 per cent level. The average mobile phone expenditures increased as well, but did not in so in a significant variation.

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We then looked at the correlations between each of the variables and found that the correlations between two measures of food insecurity were very strong, with a correlation coefficient of 0.90 and statistically significant at 0.10 level. Two mobile phone variables were also highly correlated with a correlation coefficient of 0.66, while strong correlations were observed between mobile phone ownerships and food insecurity variables. Modest correlations were observed between expenditure on mobile phones and food insecurity variables, as shown here by the coefficient of 0.34.

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We also looked at the community-level food insecurity and mobile phone variables, by the community socio-economic status and found statistically significant differences in the mean values, which means that as expected, wealthier wards tend to have lower prevalence of food insecurity, own more mobile phones, and spend more on mobile usage in the form of top-ups and airtime purchases.

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We then used the first differences between the survey rounds to capture the empirical relationship between mobile phone variables and food insecurity. The two scattered plots on your left illustrate the relationship between period-on-period mobile phone ownership versus period-on-period food insecurity, while the plots on the right illustrate period on period monthly average expenditure versus period on period food insecurity. In all of these plots, we found negative correlations in all ... which means that the community level mobile phone ownership decreases in periods where food insecurity increases, which provides and empirical support for the potential ability of mobile phone variables to estimate and monitor food insecurity.

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We also ran multilevel linear regression models for the two community food insecurity variables, with the mobile phone variable socio-economic status and agro-ecology as predictors controlling for multilevel clustering with survey year as a fixed effect. We opted multilevel modelling for prediction purposes and not to infer any causality between mobile phone use and food security, because the original idea is you make these estimates biased and inconsistent, which invalidates any inferences. We used cross-validation to formally demonstrate the benefits of multi-level modelling to figure out whether the predictive power we observed in the model is also to be expected on unseen data and if the trend model is generalizable. So the baseline model here in the X axis includes agri-ecological regions and survey year. Baseline + SES model includes socio-economic status, and baseline + mobile model includes the two mobile phone variables; while the full model includes baseline, socio-economic status, and mobile phone variables. The model performance was evaluated using the mean absolute percentage error in the Y axis, which is the average of absolute differences between the estimated HFIAS and the percentage of food insecurity, and the observed HFIAS and prevalence of food insecurity. And we also looked at the standard deviation of the absolute error. The small these errors, the better is the model. As you can see in the plot baseline + mobile model achieved a mean absolute error for HFIAS and for the prevalence of food insecurity compared to the baseline model. And in estimating HFIAS, baseline + mobile model include estimation accuracy by 16% and outperformed the baseline SES model by 3%. Similarly, in estimating the prevalence of food insecurity, baseline + mobile model estimates an accuracy by 14% and was similar to baseline + SES in performance.

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So this figure here shows the observed and estimated food insecurity measures with the model containing all predictors. The line is the relationship where Y equals to X, which means that the estimated values in the X axis equals observed values in the Y axis. The closer the data are to the line, the better is the model, again. The average differences between the estimated HFIAS and the outer values was 1.013, and these estimated values explain about 52% variance of the observed HFIAS values. The average difference between the estimated prevalence of food insecurity and the observed prevalence was 0.13 and these estimates explain 46% of the variance of the observed values.

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To further test the performance of the models in different settings, we performed a cross-validation stratified by survey rounds to simulate the case where we want to know the current food insecurity status of the community but had insecurity measures from the past few years only. We assumed that the food security status in Panel 4 in 2016 was not available and we wanted to estimate that. In addition to comparing different model specifications, we also compared a model with a simple method of transf ... excuse me, where we used previous years' food insecurity to represent the current food security status in 2016. Compared to the transformative model, we followed this using variables to perform much better, where the mean absolute error was 0.98 and outperformed the transformative model by 18%. For prevalence of food insecurity, the mean absolute error was 0.168, while this was not as big as the difference compared to that of the HFIAS. The model outperformed the transformative by 5.6%.

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So as the key takeaways and future considerations, we've shown that using rigorous, validated and various approaches in different settings, there is enough empirical evidence for the potential ability of mobile phone derived variables to estimate food insecurity. The panel data allowed us to use the first differences between the survey rounds to capture the empirical relationship between mobile phone ownership and expenditure and food insecurity. We also found that using mobile phone variables greatly improve the estimation of food insecurity and can be used to better estimate community food insecurity than the socio-economic status indicator in many cases. And as for the limitations, aside from the truncated data that reduced the size of the data in 2015 and the use of recall data for this analysis that may be confounded by social desirability bias of the household and the respondent, we were unfortunately not able to access anonymized call data records that would have helped us capture additionally the full activity and probably would have helped us for real-time monitoring and also assist the short term, seasonal, or actual food insecurity status. Additionally, we were also not able not to capture data on the SIM penetration rates from the mobile subscribers, which would have also allowed us to input the models and explore real-time monitoring of food security.

Given there is availability of these call data records, further research using aggregated time-series mobile call data records and a special aggregation will help provide better estimates of community level food insecurity and real-time monitoring of food insecurity.

With that I would like to thank you all for listening, and hand it over to my colleague Giacomo.

[Giacomo Zanella](#)

Yes, that you very much to Grace and Yaritza for coordinating the whole ... and hosting this initiative. So what I'm going to present in the next 25 minutes or so is a little bit of some work... some foundation that we did and try to understand: How can we use some new technologies to capture



energy expenditures and what we would learn from this kind of data? So, how everything started? So, the idea started a few years ago when we looked around parks and gyms in Europe and in the US, and we saw that everyone was wearing those fitness bracelets, like a Fitbit or Apple Watch. Those are accelerometers, so they capture the movement and are able to give you the energy expenditure at the end of the day. So we thought: Well, what can we learn using these technologies in a very different environment, an environment like rural areas, where physical activities on the field can be very demanding. So after ... after... thinking about it, we were able to run a few pilots and then a larger project that really tried to understand the potential but also the limitations of these technologies. This would not have been even possible without a lot of partners that really helped us to develop our research, but also to implement our research on the field. The fundings from Immana really provide a huge boost to the research, and those I want to acknowledge are our partners on the field, the University of Development Studies in Ghana, the National Institute for Development in India, and VaRG in Nepal, that really helped us to implement the project on the field. And then the University of Reading and Tufts University as well. In addition, I don't want to forget all the enumerators, really the people that actually ran all the data collection, and as we will see, the data collection can be quite demanding with this methodology. So we want to acknowledge all the enumerators in Ghana, India, and Nepal. But really without them we would not be able to do the research as much as with the participants. So, why then is it important to capture physical activity in rural LMICs? The first consideration is that if you look at literature, we see that a lot or most of the studies really focus on food intakes or changes in diet, but the changes in physical activities is not very much studied so far. There are different reasons why that is the case. One of them is that so far, capturing physical activity on the field was something quite very expensive, and something that was possible of doing in a sort of a lab environment. Instead, with the new technologies, we are able to get a much better understanding of the physical activity component. The second point that we think is very relevant is that we often talk about agriculture intervention, but introduce some sort of innovation. And we are not capturing at the moment what is their contribution of those innovations in terms of physical activities. For example, new technologies may provide higher yields, but also a higher physical activity level to grow that kind of crops. Other infrastructural mechanization-led interventions may provide an effect on the energy expenditure component of the people that are affected. So, not taking into account energy expenditure, we feel that it's a gap that is worth exploring and shed some light on it. And more specifically, when we talk in terms of agriculture and nutrition linkages, again the physical activity level should go in pair with the energy intake, so the food intake component. So we think that is a gap that with this methodology we are able to fill. So, why does this matter then? Why what we are doing matters? What I was mentioning in the previous slide, that is if we don't focus just on the energy-in component, so the food intake component, but also with the energy-out component of physical activity, then we have a more granular understanding on not what just people eat, but also how people will spend their energy in a way that we can provide... we can assess the level of food intake that is optimal for that specific livelihood. We also have in retrospect a partial understanding of how much calories individuals need every day. So we have some sort of a norm - 2000 to 2500 calories, for example. But then that is a mean, and we saw very much how in rural areas of LMICs actually livelihoods are very diverse. Some people tend to have a much more demanding livelihood lifestyle than others, but also in terms of rural transformation. We might think that in the future, rural people may spend less energy than they are doing now. So how will these affect the energy intake. And more in general terms, I think that energy use component will provide a much better understanding of the current impact of introduction of different innovations. These can be very much disaggregated on many different levels, it could be gender, it could be different kinds of households, but also in terms of how people behave and their choices that they make. So, in this presentation, I will start looking at introducing the methodology and the study design, then the following three parts will be three case studies. So the project was mainly designed to develop a methodology that could implement accelerometers in rural livelihoods. But we also wanted to provide a threshold... sort of case studies in which we can show how this data can

be used. Then I will finish looking a little bit at the limitation of the study and also how this methodology can be expanded. So in terms of methodology, we use what we call accelerometer. Accelerometers are small... very, very small sensor that capture movement. So if you have a mobile phone that was built in the past 10 years or so, inside there is an accelerometer. Inside all the fitness trackers, like a Fitbit or Apple watch or many other kinds of devices, there is an accelerometer. And that accelerometer captures the movements. So once we know the movements in terms of direction and intensity, we can capture the energy that is required. Something that is important to highlight is that the devices do not capture effort, they just capture movement. So just to give you an example, if you work or you work with a maxi bag of mesh on top of your head, the kind of measurement that we get from the accelerometer is the same. So this is a limitation that we need to keep in mind when we discuss our results. In terms of devices, we use the actigraphs. If you see from the photos on the right, three of our participants from India, Ghana and Nepal, you see that they sit on the waist area usually on the left or right hand side depending what is the dominant side of the body. And you will see that they are quite small. And we use those devices versus some more commercial devices because those are medical research-graded devices. What it means? It means that the accuracy is greater than what we could get with a more commercial device. But more importantly, we have access to the raw data. So we are able to analyze the data and to compute the energy expenditure without relying on algorithm ... proprietary algorithm from other companies. So they are very small devices. They are suitable to be used throughout the day, and the batteries around 30 days. Being medical devices and research-graded devices, there is not really any screen, any on/off switch. So there is little temptation for potential participants to make other uses of that. And importantly, those devices have been used and validated in many different contexts. So we can rely on scientific robustness. So what we have done... so in the next slide, we can see three different streams of data that we have combined in the methodology that we have developed. So the accelerometer is capturing the energy expenditure in addition to energy expenditure, we were administering daily surveys to our participants that would capture food intake, so what people were eating every day and how people there were spending their time: so a time or what we call a time use questionnaire. So having those three streams of data allow us to triangulate... allow us to cross-check and cross-reference the data stream from one... the data from one stream and another in a way that can really provide a different dimension into the rural livelihood of the people. In terms of geographical focus, we looked at three different countries: Ghana, India and Nepal. And we selected our participants in a very specific way. In the next slide we can see how we selected 40 individuals: so 20 households, and in each household, we selected the head and the spouse to be part of our study. And they were invited to use the accelerometry data for seven full days for four weeks across the agricultural season. So we selected 20 households in each country. In each country, in each household, both the male and the female took part in the study. And they wore the accelerator for one week, a full week four times throughout an agricultural season. That allow us to capture different physical activities... different activities throughout the agricultural season. So activities during the land preparation, activities during the seeding and sowing, activities during the land maintenance, and finally during harvest. During the seven days, every day, an enumerator was visiting the individual and was administering a food intake questionnaire and a time use question. In total, even if you see that we have a small number of individuals because there are only 40 for each country, we ended up with more than a thousand days of data, which we analyzed at our level. So we ended up with more than 26,000 hours. The

data is publicly available, so everyone can have access to the data, and everyone is free to work with the data set. We have the link here and the publication that goes with it. So I would like then to start with the first case study. And we start with livelihood descriptions. So let's see how this data can provide some very simple descriptive, but also quite insightful descriptive. We focus on Ghana for this specific case study. So the first graph that I wanted to show you is simple, the total energy expenditure by gender. So in here we have on the X axis, we have the calories per day. The blue lines are males and the red lines are females. And when we look at the graph, we can see how the distribution looks like. So we see that the males have the right tail, it's more on the males, whether 50 males have the left tail. And this is simple kilocalories - total energy expenditure in a day. However, the requirement for males and females can be quite different, the requirement that in terms of energy expenditure... the energy that you require to keep, let's say, your body alive. So let's assume...if you ... what is the energy that you require just to keep your body alive is what we call a basal metabolic rate can be fairly different between males and females, because it depends on the weight, age, and the height. So in the next slide, what we did is that we looked at what we call physical activity level, which takes into account this basal metabolic rate and is a better way to possibly compare activities for male and females. And the graph... what we get from the graph, we see a different picture than what we have seen earlier. We see that actually, females, in this case of Ghana, have a higher physical activity level. We can disaggregate this data, for example, by a season, and that is what we have shown here. So we can start looking at how male and female actually have different physical activity patterns throughout the agricultural season. We can look at the day level as well. And this is in the following slide when for each hour of the day, we look at... we look at the physical activity level in terms of ... 12 a day. So we see that females have a higher physical activity level 12 a day, and we see a fairly large peak of differences, in the late afternoon, when often females then to have cooking domestic activities, whether males can possibly not having such demanding activities. So far, what we have seen is just focusing on the energy expenditure, but then we can start introducing some of the other stream of data that we have. And this is what we have done in this graph. In here, we have the caloric adequacy ratio, which is a ratio between energy-in and energy-out. So if it's 1, it means that you are eating as much as you are consuming. If it is less than 1, there is a gap into your food intake. If it's greater than 1, there is... you are eating more than what you are consuming. So, in here, you can see again a distribution between males and females, and we get a general picture of what the patterns might be. So here, those are very much some descriptive statistics just to give you a flavor on how we can use data. Previously, we were really not able to capture energy expenditure in such a detail. So already a kind of... a kind of... a kind of general flavor of what we are doing. And already, descriptive statistics is something that we can get several insights. So, if in the second case study we go a little bit further, and we do an analysis in which we want to look at the effect of "drudgery reduction". In the coming couple of case studies, I'm not looking at the technicalities of what we do. There are the references to the paper if you are interested or you are free to contact me, but the aim is very much to provide you a snapshot of the kind of the kind of analysis that we can do with this data. The research question that we wanted to ask in this paper is: What are the implications if we substitute one hour of light activity for one hour of moderate and vigorous activities? So we simulate: if our participant were to have... to shift their pattern of physical activity toward greater... light activities, so a more... a reduction in the drudgery that they do on the field. And we look at India and we look again at gender differences, but also at how different the impact would be different for different kinds of

households. So, in here, I reported the data in the coming table. I reported the data from a different kind of household. We split our sample between “irrigated” and “not irrigated” households, households that are at the top wealth index and households that are in the lower wealth index, small land owners, large land owners, small dependency ratio, and large dependency ratio. So this is a classification of the household. And then we have how the energy requirement would change for males and females. And from here, what I wanted to highlight... I’m not going in to the details of the results, but what I wanted to show is that how the simple question on how the pattern would change, in terms of physical activities, we get very different results, not just between males and females, but also between different household characteristics. So this is something to keep in mind when we think in terms of program interventions... the fact that we are going to do in terms of drudgery reduction. It will be different for different households, but will be different also for males and females. In the final case study, we focus more on the patterns of allocation of time and the allocation of energy expenditure in the rural livelihood ward. So in this paper what we do, we very much take... exploit the rich data that we have on time use and energy expenditure, and we wanted to look at differences across males and females, but also across differences. And we want to look at the different trade-offs that people need to experience. In this cases, I will show you the data from Nepal. So, it’s the case study for Nepal. Again, I’m not going into details for the methodology, but I just wanted to show you the kind of insight that this sort of... this sort of data can provide. There is the link to the paper, so you will find all the details and the technicalities in there. So, in here, we have in the following slide, we have two three different graphs. The first one is about the productive work, the second one on reproductive work, and finally, leisure time. For each of those graphs, we divided the plot between men and women, and for each of those, we have in blue energy ratios. So what is the proportion that you spend in terms of energy in productive work, and in red the proportion of time that you spend? And then, we divide that by different seasons, and you see that season the X axis, 1, 2, 3, and 4. So the idea is that then we see the result from the productive work, first, we can see how the blue dots are all above the red dots. What it means? It means that the productive work tends to be energy demanding activities, so people are spending more energy than time proportionally in productive work. But also, we see a little bit of difference between the patterns between males and females. But more importantly, we see how during the different season, there is a distinct pattern, so the allocation of time and the allocation of energy that men and women do in the pool for productive work significantly changes throughout the agricultural season. In the following two graphs, what we see... we see the reproductive work as we expect, it is quite lower in terms of time and energy, and we see that the red and the blue dots, they kind of... they are overlapping. It means it’s not either time demanding or energy demanding. Instead for leisure activity, we see how distinctively the red dots tend to be on the higher end than blue dots, meaning that the leisure activities tend to be more ... relatively more time than energy-demanding. And this is interesting because we can also see the kind of trade-offs that people need to do when they allocate their time and their energy throughout the day. In this case that we see, we have some signal on how women need to trade-off some of their leisure time, because they need to look after reproductive work. Again, this is very much a snapshot, but I wanted to provide you a kind of ... a snapshot of the richness of the insight that we can get with this data. So I would like to conclude with looking a little bit at what we learned out of this process. First of all, we have a manual for practitioners so now to use accelerometer in LMICs in which we try to summarize our experience if other practitioners are interested or policy

makers are interested to apply this methodology. One of the important things that we learned is the amount of trainings that goes into the project. Devices are not ... are not rocket science, but they require a clear and strict protocol on how to use them, deploy them to the field to downloading the data. So in terms of training, it's something that we had to really work quite hard on. And of course on cost implication even if you use the same devices throughout the agricultural season. This is what we did. Devices are not cheap. And that allows often to work with possible just small samples. You have seen that we have worked with just 40 individuals in each country, and we have already very, very rich data. So having a large sample... yes, it will provide... it will imply much larger cost but also a very large amount of data. About accelerometers, what we are doing is... we are looking at ...we collect data... accelerometers collect data, one data point 30 times every second, so you understand we ended up with millions of data points. So that is important to keep in mind. And the second consideration is that accelerometers are a very fast evolving field, and it then would be impossible to think that potentially in the future you can use mobile phones. Possibly you can even use mobile phones that participants already have their own. So that is something a consideration that is important to take, how ...maybe not just a couple of years' time... the way in which we collect the same day, that could be very, very different. In terms of future expansion, as I mentioned, the aim of the project was very much to develop this methodology and to show some case studies to showcase what the data can be. But also if you have a much more targeted situation, then the insight that you can gain can be much more targeted as well. For example, you might want to provide... to focus on a specific group or on specific individuals, for example, you might want to do a study on adolescents, a study on elderly or specific individuals, think about the public work if you are interested in the productivity of public work. Those technologies can be used in program evaluation. So think if you want to introduce a new agricultural technology, you want to do some sort of a communication campaign. And those data from the accelerometer can really integrate the data that you would already collect for a dimension as physical activity that you were not able to collect any other way. While we are focused on the rural side of livelihood, there is definitely a scope to look at urban areas as well, with the rural transformation as well, and the kind of level of sedentarization that we can find in urban areas of LMICs as well. You can focus more on productivity, looking for example at the ill effect of productivity. Think about possibly you might want to think what is the effect of malaria on agricultural productivity. A way to do that is possibly try to capture the movements and that is a very good proxy for that. And with this I will conclude an area that is very, very important. It is the idea of activity recognition. So how ... what can we gather some information from the raw data on what people are doing? So at the moment we match up time use with energy expenditure, but time use is a recall information. Can we from the accelerometry data try to proxy the kind of activity people do? So those are the kind of future expansion and ... just to give you a kind of things that... a kind of flavor, but there are many, many others that can be suitable for this methodology. So to conclude, and this is kind of wrapping up a little bit what Robin said earlier, and more generally, how using those new metrics... what might be the implications for policies and programs? So what did we learn? So the first point that we wanted to see, it's very much that those technologies and those new metrics offer many opportunities to collect new data, but that doesn't mean that they replace what might be possible or what has been collected already on the ground, but we see it very much rather as a complementary approach, something that you can think if you are not able otherwise or if you want to have a greater insight in a specific consideration. And like many... many methodologies, there are

some limits and benefits. And this is even more true when we talk about technologies. What is very important is that we need to identify the right tools for the job. There is no point in applying a tool that is not right for what we want to do. One of the main contribution of those methodologies that we have shown today is that they can provide nearly real-time data, so we can very much have an assessment of program without waiting for a long time, and possibly for collecting data or for analyzing the data later on. And finally, a little bit on the concept of scalability and cost effectiveness, which is paramount when we talk about policies and programs. And these should be taken into consideration regarding what that would be using a conventional assessment in terms of food security or physical activities, and really try to balance what might be the additional insight that you would gain using those new methodologies. So with this, I would like to conclude. And again, I could like to thank all the collaborators that for the past few years have been working on the project. This is very much a joint in the team effort, so I'm very lucky to present it but there are so many people that have been working very, very hard on this, and of course Immana for the funding of the project. So thank you so much for all of you for attending this initiative. And I will give back to Grace for the Q&A session.

Grace Namirembe

Thank you so much to all the presenters. So in the Q&A, I will start with Richard Kinney's question and that's to Robin and Lichen:

What are the privacy concerns of using data from so many people's cell phones?

Robin Shrestha

Thanks Grace. Maybe I'll take a step and then listen. Please feel free to come in. For this particular analysis, we did not use any call on data records. That was one of the limitations for your analysis, but I agree there are privacy issues, even at a higher spatial aggregation and one other reason why we wanted to do it at the community or at the world level... why we focused on the world level, was because of the privacy at the household level provided we had access to the call data records. But yes, that privacy issue is a concern.

Robin Shrestha

Yes, I agree Robin. I think one of the advantages of this study is we studied community level, so this somehow is a higher personal privacy, somehow, so this is a good thing of this study.

Grace Namirembe

Ok. The research on the accelerometers is a groundbreaking one. I'm intrigued to know how the measurement of dietary intake was done for participants in Ghana. How did you measure dietary intake?

Giacomo Zanello

Yes, dietary intake was measured with a 24 hours call of food intakes and it was using the usual methodology of dividing the day in six different meals, and for each meal we were recalling what people were eating. In certain cases we had to build some composition tables because the recipes were not for that specific communities. They were not... some of the dishes were not in the food composition tables, so we integrated some of ... we did a kind of a cooking session, in which we integrated that, and that is the way in which we collected the information.

Grace Namirembe

Still to Giacomo. Caroline would like to know what was used alongside the movement data for the total energy expenditure estimation.

Giacomo Zanello

Yes, so that is very interesting. So accelerometers provide a different kind of information, so energy expenditure possibly is the most obvious one, but also provides the percentage of time that individuals are spending in different intensity of work. So there are different thresholds that you can use. And usually we divide activities from sedentary light activities or moderate activities or vigorous activities. And this is a proxy for effort to some extent although it technically is an intensity. So we have another work that we are doing. We work mainly on those intensity activities, but also the second case study when we say: what if people instead of doing up moderate and vigorous activities they do one hour more of light activities every day. And that is very much how we are using this other information from the accelerometers. The accelerometer provides also a number of steps if you are interested in more in the mobility of individuals, and they provide some other information that are more specific and technical but those are the kind of the main data that you can get from accelerometers.

Grace Namirembe

Thank you. Marilyn is asking you reference is smartphones, and then revert to mobile phones. Do you distinguish between the basic early phones that use SMS technology from the current smartphones with much more improved technology?

### Robin Shrestha

Thank you, thank you for the question. I think Patrick already has responded to this. Yes, smartphones are better for accessing digital information and better tracking the cell phone user data, but this work that we did was based on any cell phones that the household reported they owned in the household. So I hope that answers the query about the smartphones.

### Grace Namirembe

Yes, and then, what are the future steps for this project? That's for you Robin and next question, how will the results be applied to alleviate food insecurity?

### Robin Shrestha

Yes, I think the future steps would be to get access to the call data records and improve the models that's we've worked on, provided that would... I mean that would provide us maybe a potentially performed real-time monitoring of food insecurity, but also kind of take into account the seasonal variation and fluctuation in food security but also look at the accurate shortages or accurate food insecurity status. The other thing is what we used in our analysis was the number of phones and in addition to the cell phone data, if you can have access to the same subscription rates. That would also help us track what ... how many phones are being used, how the penetration look like in the households and at the community level, and you know make a model that can actually do a real-time monitoring of the food security status at the community as well as at the household level. I don't know Lichen, do you have anything to add?

### Lichen Liang

Thanks Robin. I think Robin already mentioned several key points for this project. The next steps and they'll be better, we can get the real data from operators. So because cell phone data is just definitely richer than what we have had so far, and more than just ownership and the expenditure. So there's many other features from the mobile data. We can track some personal spending time and the social network. So this information is very useful, so we'll see there in the study on ownership, it can be very good predictor for the food insecurity. But we know the time change, and society change, and technology change, so this kind of relationship may change over time. So this is a very big concern for the model. So if the model can work for this year, maybe the model won't work for next year. So mobile phone data will provide much more information, and we can develop some new features, so those features may be later on and replace this mobile phone ownership proxy indicator. So maybe we got better results. So these are many things we can investigate. Another thing very interesting is in this data set, we definitely show there's an interesting relationship between the mobile phone on usage and food insecurity, but we are... we can only show the relationship, but we cannot justify it is a causal relationship. The causal relation is important, you can justify it because this has the potential... policy implication so either we think that there may be some interesting cause or effect from mobile phone usage like in this case, the mobile phone ownership that can be increasing mobile phone ownership or mobile phone penetration, something that can benefit the food insecurity.



So if we can really use a rigorous economic method to justify this assumption; that will provide another hint for the policy and implementation. So that's it, thanks. Back to Grace.

Grace Namirembe

Thank you Lichen. Giacomo, Erika is asking: have you explored how women or caregivers accommodate the trade-off of lack of time for reproductive work during time-demanding seasons for agriculture... for agriculture productive work such as seeking social support?

Giacomo Zanella

Yes, this is a very, very good question, and something very much that there is opportunity for research. But we haven't done that. We haven't done that because in our sample, we didn't have many caregiver women, I think only a couple, one or two in each country. So the work was not designed around this specific topic, so we are not able to look at that, but I really see how the methodology can be employed, can be used to look at specifically this topic. So definitely, there is an opportunity for some interesting research in that area.

Grace Namirembe

And [Dick Tinsley] would like to know: Could you provide some people with additional food, such as energy, so basically as an intervention, and see if it impacts the level of effort?

Giacomo Zanella

Yes, potentially you could. You need to think carefully how you are going to design such a study. There is always the kind of consideration that there is an implicit... what we call endogeneity between a food intake and food expenditure. What it means? It means that people might have a larger physical activity if they eat more and the way around. So it's... we need to really think carefully how to find a way to disentangle the direction of this and the pathways of this causality link. But yes, that is definitely something that is possible and something the accelerometer would be able to assess in terms of output, in terms of physical activity levels.

Grace Namirembe

Thank you. [Lydie] is asking: Some households in rural communities cannot afford cell phones. Was the study able to account for food insecurity in such cases?

Robin Shrestha

Yes, that is true, yes. But what we did for the analysis is compare the clusters of households that had the mobile phone use against HFIA at the community and ward level. So the clusters

were at the ward level. So that did kind of explain also that the least households... the households that used the least of the phones were the households that were the most food insecure. But we did not dive deeper into the household level. We looked at the community. That is what we did. Does that answer the question, Grace?

Grace Namirembe

I think so, thanks. Christopher to Giacomo: Can you subtract the basic metabolism from food intake, then get an estimate of how people are capable of working each day? And if ... yes... sorry, let me read that again. Can you subtract the basic metabolism from food intake, then get the estimate of how people are capable of working each day?

Giacomo Zanella

Yes, if I interpret correctly the question, yes you can do that, in a sense that the accelerometer captures the physical activity. On top of the physical activity, you need to add, what we call the basal metabolic rate. So the basal metabolic rate is the energy that your body requires just to function, and it tends to be quite high, around 66 percent of the total energy expenditure. So knowing these two information, you could potentially say to what extent food intake meets basal metabolic rate or meets the total energy expenditure, which is the basal metabolic, plus what we call the activity energy expenditure. Activity energy expenditure is the energy expenditure that you do during activities throughout the day.

Grace Namirembe

So we have about three questions about food insecurity. One is: Define food insecurity versus food security and how did you measure it? Was it at the individual or household level? And Robin, how did you measure the prevalence of food insecurity in Nepal?

Robin Shrestha

Lichen, do you want to take this one?

Lichen Liang

Okay. So for the food security, we have some measurement at the household level. So this is based on our HFIAS calculation and it has 27 questions. People answer the questions based on their feeling about the food insecurity in the past 30 days or something. And then they are just scaled from the year 0 to 30 to indicate how severe the food insecurity is. So this question can also categorize the household as food insecure and food secure, so this way and we can somehow calculate as the percentage of households in the community that are food secure and

that are food insecure. This is the way we calculated the community level for the security score and the community level for the insecure prevalence. Does that answer the question?

Grace Namirembe

Yes, yes. And maybe we can add a link on the website for all the details of how it can be measured. So in the interest of time, I'm going to invite participants... I mean all the presenters, to give concluding remarks. So, we'll start with Giacomo.

Giacomo Zanella

Yes, so I think what we wanted to present today is how a new methodology can shed light into an aspect of rural livelihood that has not been looked at much. This is possible with these new technologies, and I hope that with this presentation we have seen we have provided not just the intuition around the methodology, but also an insight on which kind of information you can get and how you can use this new stream of data, mainly in combination with other streams of data, such as time use and food intake. And also it is always important also to highlight the limitations of what this methodology can provide. And this idea that we see that it's not as a substitute of data can be collected but very much as a complement, an additional information but we believe that in a certain setting it can really improve our understanding of specific dynamic of the rural livelihood to a much greater degree or a more granular degree as well.

Robin Shrestha

Yes, I would first like to thank all the participants for tuning in and for all the engaging questions. I'll just echo what Giacomo said that you know we need to improve these metrics, and there are limitations, but we have to look at these limitations as an opportunity to improve the metrics in real life settings and kind of look at how this can support the adaptive management where you know data are not available, where there's limited data or you know when there is uncertainty. How can we use this global metrics and tap into those conditions and situations? And as Giacomo said, we still need to evaluate cost effectiveness of using these new metrics in the interventions versus assessments. And we also need to explore the applications of global data in development research and programs. But we also need to be able to ... and a lot of the participants did raise this... maintaining some data privacy and protecting the privacy of human subjects and confidentiality and minimize those compromises. And thank you again.

Grace Namirembe

This concludes our webinar today, thank you everyone for participating. And just as a reminder, there's an upcoming webinar on ecology and prevention of linear growth faltering in Nepal. That will be on September 30<sup>th</sup>, at the same time, 9 a.m. To register for these events, visit

nutritioninnovationlab.org or advancingnutrition.org. And again, the recordings and slides for each webinar will be posted on our website. So please visit if you want to review this session. Thank you everyone for coming. Goodbye, thank you Chris, thank you.



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