

Coproducing Weather Forecast Information with and for Smallholder Farmers in Ghana: Evaluation and Design Principles

Talardia Gbangou ^{1,*}, Rebecca Sarku ², Erik Van Slobbe ¹, Fulco Ludwig ¹, Gordana Kranjac-Berisavljevic ³ and Spyridon Paparrizos ¹

¹ Water Systems and Global Change Group, Wageningen University & Research, P.O. Box 47, 6700 AA Wageningen, The Netherlands; erik.vanslobbe@wur.nl (E.V.S.); fulco.ludwig@wur.nl (F.L.); spyros.paparrizos@wur.nl (S.P.)

² Public Administration and Policy, Wageningen University and Research, P.O. Box 8130, 6700 EW Wageningen, The Netherlands; rebecca.sarku@wur.nl

³ Department of Agricultural Mechanization and Irrigation Technology, University for Development Studies, Box TL 1350, Tamale, Ghana; novagordanak@gmail.com

* Correspondence: talardia.gbangou@wur.nl

Received: 16 July 2020; Accepted: 11 August 2020; Published: date

1. Summary of Local Forecast Indicators for Daily Rainfall Forecast in the WeatherApp [29]

Table S1. List of the local forecast indicators for the daily rainfall forecast at Ada East district used in the WeatherApp (adapted from [29]).

Indicators Name	Indicator' Signal Used for Daily Rainfall Prediction
Wind	When strong winds blow from the sea (usually from West to East direction)
	When the wind is blowing from the sea carrying dust (West-East direction) with high intensity of the sun
Halo (around the Sun)	If at sunset there is a red circle around the sun
Sun	If high intensity of sunshine is observed
	If high intensity of sunshine and dust-wind blowing (from West to East) is observed
Bird (Torle, Ploceus cucullatus)	Make a lot of sounds
Frog	When frogs start croaking a lot
Pig	When pigs catch the grass and turning around it
Moon (distribution)	When the moon shape is curved such that the shadow is on the left side
	When the moon shape is curved such that the shadow is on the right side
	When the moon shape is curved such that the shadow is on the top side
Worm (Abotele)	Spread all over the grass after a previous rain
Scorpion	When big black scorpions appear frequently on the farm
Clouds	A thick cloud appears at the eastern side of the sea
Ants	Carry their food or eggs to their holes
Dew	If from mid-night to the following morning there is a lot of dews falling

2. Farming Decisions that Were Made Using the Forecasts and Data

Table S2. Farming decisions that the co-produced experiment information has helped to support. It gives the percentage of decisions that were more of interest by the 28 participants (22 Farmers and 6 extension agents).

	Prepare land	Amount of water to allocate	Seeding/ transpla nt	Fertilizing	Pesticide applicati on	Labor/we eding	Othe rs
Rainfall monitoring data	64%	29%	68%	64%	50%	61%	50%
Daily forecasts from farmers	50%	25%	57%	50%	46%	46%	50%
Daily forecasts from scientific models (meteoblue)	57%	29%	61%	57%	46 %	46%	50%



Table S3. Significance of the results on the engagement, usability, usefulness, understanding and decisions improvement when considering a binomial distribution for the medium and high categories of responses. (for farmers).

Evaluation Metrics	Digital Items or Tools	Category Level	Functionality	Number of Success	Total Number of Farmers	Probability	Success Probability	p-Value	Sign 0.1 (+); 0.05 (*); 0.01 (**); 0.001 (***)
Engagement		Medium and High		15	22	0.5	0.973761	0.026239	*
		Low		7	22	0.5	0.0669	0.9331	
Usability	WeatherApp (After experiment)	Somehow and Very easy	Manipulation	16	22	0.5	0.99155	0.00845	**
		Not easy and NA		6	22	0.5	0.026239	0.973761	
	WhatsApp (After experiment)	Somehow and Very easy	Graphs	16	22	0.5	0.99155	0.00845	**
		Not easy and NA		6	22	0.5	0.026239	0.973761	
	Rain gauges (After experiment)	Somehow and Very easy	Reporting	15	22	0.5	0.973761	0.026239	*
		Not easy and NA		7	22	0.5	0.0669	0.9331	
Usefulness /Relevance	Tools	Somehow and Very Relevant	Internet	14	22	0.5	0.9331	0.0669	+
		Not Relevant and NA		8	22	0.5	0.143139	0.856861	
		Somehow and Very Relevant	Rain gauge	18	22	0.5	0.999572	0.000428	***
		Not Relevant and NA		5	22	0.5	0.00845	0.99155	
		Somehow and Very Relevant	Smartphone	17	22	0.5	0.997828	0.002172	**
		Not Relevant and NA		6	22	0.5	0.026239	0.973761	
		Somehow and Very Relevant	WeatherApp	18	22	0.5	0.999572	0.000428	***
		Not Relevant and NA		5	22	0.5	0.00845	0.99155	
		Somehow and Very	WhatsApp	16	22	0.5	0.99155	0.00845	**

		Relevant							
		Not Relevant and NA	7	22	0.5	0.0669	0.9331		
Understand ing	Information and data co-produced	Somehow and Very Relevant	local forecast	18	22	0.5	0.999572	0.000428	***
		Not Relevant and NA		5	22	0.5	0.00845	0.99155	
		Somehow and Very Relevant	rainfall data	18	22	0.5	0.999572	0.000428	***
		Not Relevant and NA		5	22	0.5	0.00845	0.99155	
		Somehow and Very easy	Scientific	18	22	0.5	0.999572	0.000428	***
		Not relevant and NA	forecast	5	22	0.5	0.00845	0.99155	
	Forecast uncertainty	Somehow and highly improved		18	22	0.5	0.999572	0.000428	***
		Not improve and NA		5	22	0.5	0.00845	0.99155	
	Rainfall distribution	Somehow and highly improved		18	22	0.5	0.999572	0.000428	***
		Not improve and NA		5	22	0.5	0.00845	0.99155	
	Decisions	Somehow and highly improved		18	22	0.5	0.999572	0.000428	***
		Not improve and NA		5	22	0.5	0.00845	0.99155	



Table S4. Significance of the results on the engagement, usability, usefulness, understanding and decisions improvement when considering a binomial distribution for the medium and high categories of responses (for extension agents).

Evaluation Metrics	Digital Items or Tools	Category Level	Functionality	Number of Success	Total Number of Farmers	Probability	Success Probability	p-Value	Significance 0.1 (+); 0.05 (*); 0.01 (**); 0.001 (***)
Usefulness /Relevance	Tools	Somehow and Very Relevant	Internet	3	6	0.5	0.65625	0.34375	
		Not Relevant and NA		3	6	0.5	0.65625	0.34375	
		Somehow and Very Relevant	Rain gauge	4	6	0.5	0.890625	0.109375	+
		Not Relevant and NA		2	6	0.5	0.34375	0.65625	
		Somehow and Very Relevant	Smartphone	6	6	0.5	1	0	***
		Not Relevant and NA		0	6	0.5	0.015625	0.984375	
		Somehow and Very Relevant	WeatherApp	6	6	0.5	1	0	***
		Not Relevant and NA		0	6	0.5	0.015625	0.984375	
		Somehow and Very Relevant	WhatsApp	6	6	0.5	1	0	***
		Not Relevant and NA		0	6	0.5	0.015625	0.984375	
	Information and data co-produced	Somehow and Very Relevant	local forecast	6	6	0.5	1	0	***
		Not Relevant and NA		0	6	0.5	0.015625	0.984375	
		Somehow and Very Relevant	rainfall data	6	6	0.5	1	0	***
		Not Relevant and NA		0	6	0.5	0.015625	0.984375	

Understanding		Somehow and Very easy	Scientific forecast	6	6	0.5	1	0	***
		Not relevant and NA		0	6	0.5	0.015625	0.984375	
	Forecast uncertainty	Somehow and highly improved		6	6	0.5	1	0	***
		Not improve and NA		0	6	0.5	0.015625	0.984375	
	Rainfall distribution	Somehow and highly improved		6	6	0.5	1	0	***
		Not improve and NA		0	6	0.5	0.015625	0.984375	
	Decisions	Somehow and highly improved		6	6	0.5	1	0	***
		Not improve and NA		0	6	0.5	0.015625	0.984375	

3. Statistics on Messages Received via the WhatsApp Group



Figure S1. Sample photos of the smartphones used by farmers and extension agents.

Table S5. Count of messages, pictures and emojis exchanged via the WhatsApp group.

Months	Messages	Pictures/Graphs (forecasts)	Emojis exchanges
April	164	33	92
May	324	70	103
June	154	61	62
July	93	35	30
Total (5th April–17th July 2019)	736	199	287

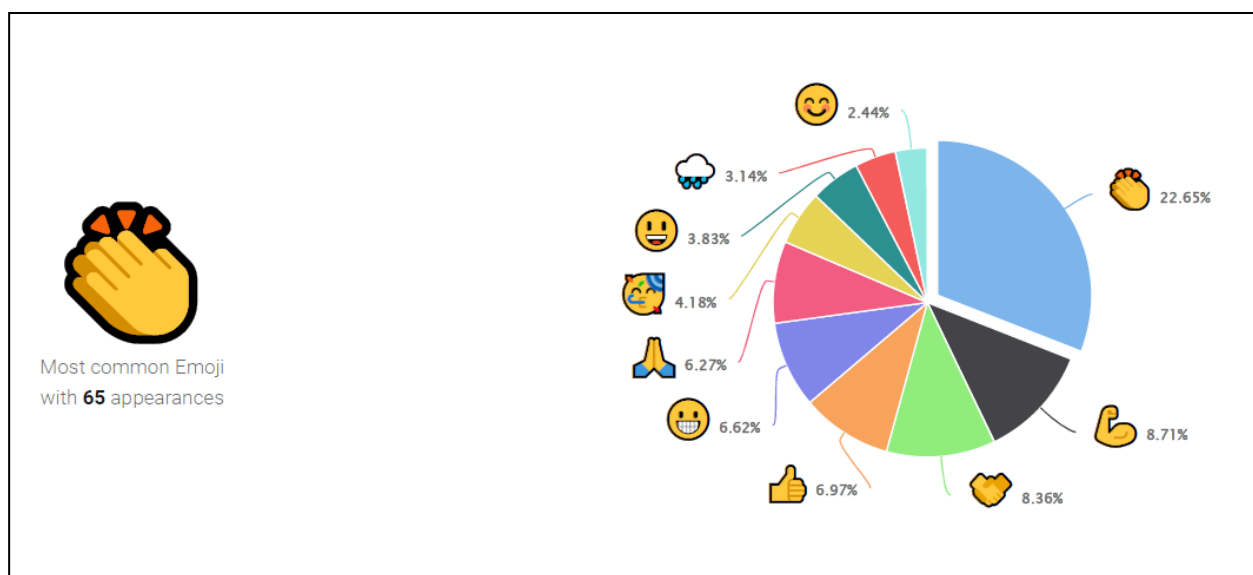


Figure S2. Statistics on emojis shared in the WhatsApp group.

4. Technical Reports on Issues by Socio-Demographic Characteristics (Age, Gender and Literacy)

Table S6. Analysis of the technical issues reported by age, gender and literacy level from a total of 92 technical issues recorded during the testing phase.

	Age		Gender		Literacy	
	Young Farmers (≤49 years)	Elder Farmers (≥50)	Male	Female	Primary School and Below	Secondary School and Above
Number of farmers	12	10	18	4	5	17
Technical issues reports (smartphone use, apps, and internet handling)	35	57	76	16	27	65
Technical difficulty ratio (Total issues reported/Number of farmers)	2.92	5.7	4.22	4.00	5.40	3.82

5. FarmerSupport Mobile APP Developed Based on Insight From this Study


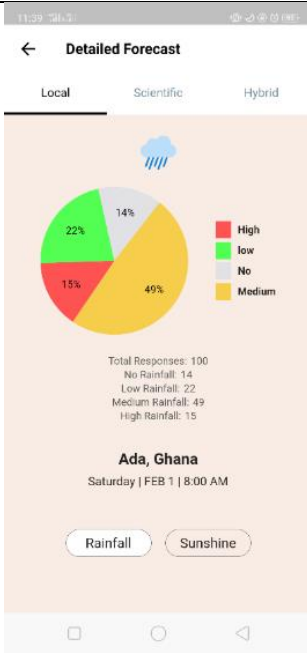

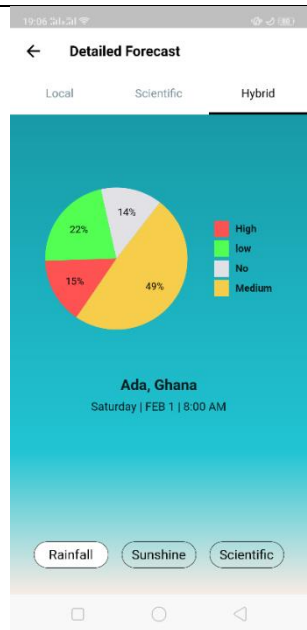
	
<p>FarmerSupport APP: Local forecast indicators collection by farmer in the study areas used for rainfall forecasting.</p>	<p>FarmerSupport APP: Local Forecast tab. This is the result of combining the local indicator used by farmers. The use of the pie-diagram format, depicting probabilities, has proven to be understandable for Ada farmers.</p>
	
<p>FarmerSupport APP: Scientific Forecast tab, based on Meteoblue forecasts.</p>	<p>FarmerSupport APP: Hybrid Forecast tab. Putting together the Meteoblue forecasts with the farmer's forecast.</p>

Figure S3. Details on the integrated APP developed under the Waterapps project (based on lessons from the present study) and which is available on google play store (<https://play.google.com/store/apps/details?id=com.spacewek.farmersupport>).