Supplementary information

This is the supplementary material for the article entitled “Verification of Seasonal Climate Forecast towards Hydro-climatic Information Needs of Rice Farmers in Northern Ghana” in Weather, Climate and Society.

List of figures

**List of Figures**

Figure S1. Taylor diagram showing the Comparative statistics of WFDEI and GMET (Tp, Tmin and Tmax data) for MAM(A), JJA(B) and SON(C). ................................................................. 1

Figure S2: Year to year average Tp (mm/day), Tmin (°C/day), Tmax (°C/day) and Tave. (Average temperature of both Tmin and Tmax) of WFDEI and GMET from 1981-2010 for MAM, JJA and SON at Tamale station... 1

**Figure S3:** Mean bias in Rainfall (mm/day) forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 1981-2010. Positive and Negative denotes forecast over estimation (wet bias-green) and underestimation (dry bias-brown) respectively for 0, 1 and 2 months prior to start of each season .................................................................................................................................................. 2

**Figure S4:** Correlation of ensemble mean rainfall forecast (ECMWF System 4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON for 0, 1 and 2 month lead times. Cross show areas of significant correlation at 95% level................................................................................................................................. 3

**Figure S5:** Mean bias in minimum Temperature forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 19981-2010. Negative (positive) showed cold (warm) biases for 0, 1 and 2 months prior to start of each season. ............................................................................................................................... 4

**Figure S6:** Correlation of ensemble mean minimum temperature forecast (ECMWF System4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON................................................................................................................................. 5

**Figure S7:** Mean bias in maximum temperature forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 19981-2010. Negative (positive) showed cold (warm) biases for 0, 1 and 2 months prior to start of each season. ............................................................................................................................... 6

**Figure S8:** Correlation of ensemble mean Maximum Temperature forecast (ECMWF System4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON ................................................................................................................................. 7

List of Tables

Table S1. Farmers’ ranking of hydro-climatic information based on importance (N=12). ........................................ 8

Table S2. Summary of skills (xxx indicates most skillful followed by xx and then x) per season and lead times .................................................................................................................................................. 9

Table S2: Questionnaire for interviews......................................................................................................................... 10
Figure S1. Taylor diagram showing the Comparative statistics of WFDEI and GMET (Tp, Tmin and Tmax data) for MAM(A), JJA(B) and SON(C).

Figure S2: Year to year average Tp (mm/day), Tmin (°C/day), Tmax (°C/day) and Tave. (Average temperature of both Tmin and Tmax) of WFDEI and GMET from 1981-2010 for MAM, JJA and SON at Tamale station.
Figure S3: Mean bias in Rainfall (mm/day) forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 1981-2010. Positive and Negative denotes forecast over estimation (wet bias-green) and underestimation (dry bias-brown) respectively for 0, 1 and 2 months prior to start of each season.
**Figure S4:** Correlation of ensemble mean rainfall forecast (ECMWF System 4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON for 0, 1 and 2 month lead times. Cross show areas of significant correlation at 95% level.
**Figure S5:** Mean bias in minimum Temperature forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 19981-2010. Negative (positive) showed cold (warm) biases for 0, 1 and 2 months prior to start of each season.
Figure S6: Correlation of ensemble mean minimum temperature forecast (ECMWF System4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON
Figure S7: Mean bias in maximum temperature forecasts from ECMWF-S4 against the verifying observations of JJA, MAM and SON from WFDEI for 19981-2010. Negative (positive) showed cold (warm) biases for 0, 1 and 2 months prior to start of each season.
Figure S8: Correlation of ensemble mean Maximum Temperature forecast (ECMWF System4) and observations (WFDEI) from 1981 to 2010 for JJA, MAM and SON
Table S1. Farmers’ ranking of hydro-climatic information based on importance (N=12).

<table>
<thead>
<tr>
<th>Information about</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Very Important</td>
</tr>
<tr>
<td>Total rainfall amount</td>
<td>17%</td>
</tr>
<tr>
<td>Rainfall distribution</td>
<td>67%</td>
</tr>
<tr>
<td>Rainfall onset</td>
<td>25%</td>
</tr>
<tr>
<td>Rainfall cessation</td>
<td>17%</td>
</tr>
<tr>
<td>Dam water level</td>
<td>75%</td>
</tr>
<tr>
<td>Temperature</td>
<td>58%</td>
</tr>
<tr>
<td>Winds speed</td>
<td>0%</td>
</tr>
<tr>
<td>Wind direction</td>
<td>8%</td>
</tr>
</tbody>
</table>

**Bolded values represent the highest percentage per information need.**
Table S2. Summary of skills (xxx indicates most skillful followed by xx and then x) per season and lead times

<table>
<thead>
<tr>
<th>Variables</th>
<th>Seasons</th>
<th>Generalized discrimination skills (GDS) (Lead times)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAM</td>
<td>JJA</td>
</tr>
<tr>
<td>Prcp</td>
<td>X</td>
<td>XX</td>
</tr>
<tr>
<td>Tmin</td>
<td>XX</td>
<td>XXX</td>
</tr>
<tr>
<td>Tmax</td>
<td>XXX</td>
<td>X</td>
</tr>
<tr>
<td>Tercile</td>
<td>Seasons</td>
<td>Tercile skills of Prcp (Lead times)</td>
</tr>
<tr>
<td></td>
<td>MAM</td>
<td>JJA</td>
</tr>
<tr>
<td>Above</td>
<td>XXX</td>
<td>XX</td>
</tr>
<tr>
<td>Normal</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Below</td>
<td>XX</td>
<td>XXX</td>
</tr>
</tbody>
</table>
Table S2: Questionnaire for interviews

Kindly read out the following introduction and consent note to the respondent, and ensure that he/she understands and thus give his or her consent before beginning interview.

Hello Sir/Madam,
My name is ………………………. from Wageningen University and Research in Netherlands. We have permission from the irrigation managers and office of the district assembly. We are currently working on a research project about seasonal hydrological and climate information services to rice farmers. Most of this research is being carried out in Northern Ghana, and you have been selected by our sampling method to ensure we received a representative picture views.

We would like to ask you some one-on-one questions that should take not more than thirty minutes. Your answers to these questions will be invaluable for the study. We will use this information to help farmers in their decisions during planting and growing rice and other crops. If you agree to participate, all the information you provide will be completely anonymous and confidential. Your answers will not affect any benefits or subsidies you may receive now or in the future. Do you consent to be part of this study? You may withdraw from the study at any time and if there are questions that you would prefer not to answer, we will respect your right not to answer them.

Questionnaire No: ……………… Community name:
………………………………………………………………………

SECTION 1:
PERCEPTION OF CLIMATE VARIABILITY

1. What kind of rice farming do you do? ☐ irrigated ☐ rain-fed ☐ both irrigated and rain-fed
2. a. Do you grow other crops aside rice? ☐ Yes ☐ No
   b. If yes, which crops? …………………………………………………………………………………
   c. which of them is your maize crop?  .........................................................................................
3. In your experience, has the TEMPERATURE for the last 30 years in this area stayed
   ☐ the same ☐ has increased ☐ has decreased ☐ is different every year ☐ do not know
4. In your experience, has the average RAINFALL for the last 30 years in this area stayed
   ☐ Same ☐ has increased ☐ has decreased ☐ different every year ☐ do not know

   Do not answer question 5 and 6 if you indicated “same” for question 3 and 4
5. In the next 10 years, do you think there will be more variability in the climate?
   ☐ YES ☐ No ☐ Do not know
6. In your own opinion, what do you think might have caused this variability in the climate? ……………

SECTION 2:
HYDRO-CLIMATIC INFORMATION NEEDS AND DECISION MAKING

7. When would you prefer to receive climate forecast information before a farming season?
   ☐ 1 month ☐ 2 months ☐ 3 months ☐ 4 months ☐ 5 months ☐ other…………………
8. When would you prefer to receive hydrological (dam water level) information forecast before a farming season? ☐ 1 month ☐ 2 months ☐ 3 months ☐ 4 months ☐ 5 months ☐ other
9. a. Do you use weather/climate forecasts information now? ☐ YES ☐ NO
    b. If no, please why not? ………
10. How would good hydro-climatic forecast information affect you?
- ☐ Good seed usage
- ☐ high yield
- ☐ appropriate water management
- ☐ save money
- ☐ enough food for my family
- ☐ others

11. What are the key reasons for you to use a climate forecasts?
- ☐ Too much climate variability already
- ☐ my existing forecast methods are unreliable
- ☐ Hope it improves crop yield
- ☐ for better water management
- ☐ Others

12. What are possible reasons / barriers for you **not** to use climate forecasts?
- ☐ Too complex for me to understand
- ☐ Not realistic in projections
- ☐ I don’t believe it is useful/don’t care
- ☐ I have bad experiences with forecast information
- ☐ the way I do it now works fine
- ☐ I don’t have access to this information
- cocothers

13. **There are a number of actions and key decisions needed for rice farming, for each decision; you might need particular type of information to make it better. Please indicate for each decision which information you need most. Rank the most important type of information with 3, followed by 2 and 1. If the information is not relevant, please leave the column blank.**

<table>
<thead>
<tr>
<th>Action</th>
<th>Decision</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-season</td>
<td>Buying seeds</td>
<td>Seasonal rainfall amount, Seasonal rainfall distribution, Rainfall onset, Rainfall cessation, Dam water levels, Temperature, Wind speed, Wind direction, do not know / none of, Others (more specifically)</td>
</tr>
<tr>
<td></td>
<td>Seed variety</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Land size and allocation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labour size</td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>When to clear Land</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to plowing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to harrowing</td>
<td></td>
</tr>
<tr>
<td>Planting</td>
<td>When to nurse seeds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to transplanting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to do direct seeding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sowing method e.g. broadcast by hand or machine.</td>
<td></td>
</tr>
<tr>
<td>Irrigation</td>
<td>when to do supplementary irrigation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Amount of water to use for irrigation</td>
<td></td>
</tr>
<tr>
<td>Fertilizer application</td>
<td>The kind of fertilizer to buy</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to carry out first fertilizer application</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to carry out second fertilizer application</td>
<td></td>
</tr>
<tr>
<td>Weed control</td>
<td>The kind of weedicide to apply</td>
<td></td>
</tr>
<tr>
<td></td>
<td>When to carry out first weed</td>
<td></td>
</tr>
</tbody>
</table>
control
When to carry out second weed control
Which time to spray weedicide
Which weed control method to choose(e.g. hand or weedicide)

Pest control
The kind of pesticide to buy
When to carry out first pest control
When to carry out second pest control

Harvesting
When to start harvesting
Which method of harvesting to choose(e.g. by hand or machine)

14. Which medium do you prefer to receive information stated in question 13?
- Radio
- mobile phone (text messaging)
- Extension officer
- Irrigation manager
- TV
- Internet
- Head of Farmers Association
- specially trained personnel
- other

SECTION 3:
BRIEF BIOGRAPHICAL INFORMATION

15. Name…………………………………………………………………………………………

16. How old are you (age in years)?
- 21-30
- 31-40
- 41-50
- 51-60
- 61-70
- above 70

17. Gender?
- Male
- Female

18. What is your highest educational level attained?
- Elementary /primary
- Middle school certificate/JHS
- SSS/O-level/WASSCE
- Tertiary
- No formal Education

19. a. What is your farm size on the irrigation scheme (in acres)?
- less than 1
- 1 – 1.9
- 2 - 2.9
- 3-3.9
- 4–4.9
- 5 -5.9
- others

b. What is your farm size outside the irrigation scheme (in acres)?
- less than 1
- 1 – 1.9
- 2 - 2.9
- 3-3.9
- 4–4.9
- 5 -5.9
- others

20. What is your household size?
- 1-5
- 6- 10
- 11-15
- 16-20
- 21-25
- above 25

21. How long have you been doing rice farming (years)?
- 1-5
- 6- 10
- 11-15
- 16-20
- 21-25
- Above 25

22. Would you like to stay involved in our work?
- YES
- NO

23. Would you be interested in participating in a feedback workshop on this survey?
- YES
- NO

24. Is there anything else you would like to share with us? Something we should look into in more detail?

THANK YOU FOR PARTICIPATING

(To be filled by the interviewer)

Specific circumstances observed during interview (e.g. whether interviewee was struggling with questions or could answer easily. Whether interviewee seemed particularly interested and a good candidate to follow up with)