Effect of canal conveyance efficiency enhancement on crop productivity in Nepal under climate change

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BACKGROUND:

- Nepal is expanding irrigation facilities to cope with the projected increase of drought periods in the growing season (Dahal, 2023).
- Irrigation efficiency in Nepal is around 30%, well below the potential efficiency of 60%. The goal is to increase efficiency to at least 50% by 2027 (DoWRI, 2019).
- Canal conveyance efficiency, operational efficiency, and application efficiency are three aspects which influence irrigation effieciency. More water is lost in longer than in shorter canals. Lining canals with bricks, plastic, or concrete reduces water losses (Irmak et. al,2011).

Fig.1. (a) earthen canal with low conveyance effieciency with high seepage and percolation loss , (b) concrete lined canal but not well maintained with low effieciency, (c) high effieciency well maintained canal lined with concrete .

RESEARCH QUESTIONS

- How will a change in canal conveyance efficiency (CCE) from 30% to 50% influence crop water availability - and thus crop yields – under **current to near future** climate conditions?
- How will a change in CCE from 30% to 50% influence crop water availability - and thus crop yields - under climate conditions at the **end of the century**?
- How large are the benefits with an **increase to 70%** CCE?

METHODOLOGY:

- Scope of the study:
  - **Canal conveyance efficiencies**: 30%, 50%, 70%
  - **Crops:** rice, maize, wheat
  - **Climate change scenarios**: SSP1–2.6 (low emissions), SSP3–7.0 (high emissions), and SSP5–8.5 (extreme emissions)
  - **3430 simulation units** covering Nepal
  - Crop model simulations were performed for three periods **2022 to 2050** (Near Future), **2050 to 2075** (Mid Century) and **2075 to 2100** (End century)
- The **EPIC crop model** was used for the biophysical crop modelling (Williams et al.,1989).
- **Model calibration** was done adjusting crop parameters iteratively to match simulated yields with reported yields at the district level from 2015 to 2021
- **Climate data** projections were generated using 3 general circulation models (GFDL-ESM4, IPSL-CM6A-LR, and MPI-ESM1–2-HR), and bias adjustments were made as part of CMIP6 and sourced from ISIMIP3b.
- Results were aggregated at the district, province, and ecoregion levels for analysis for each time frames.

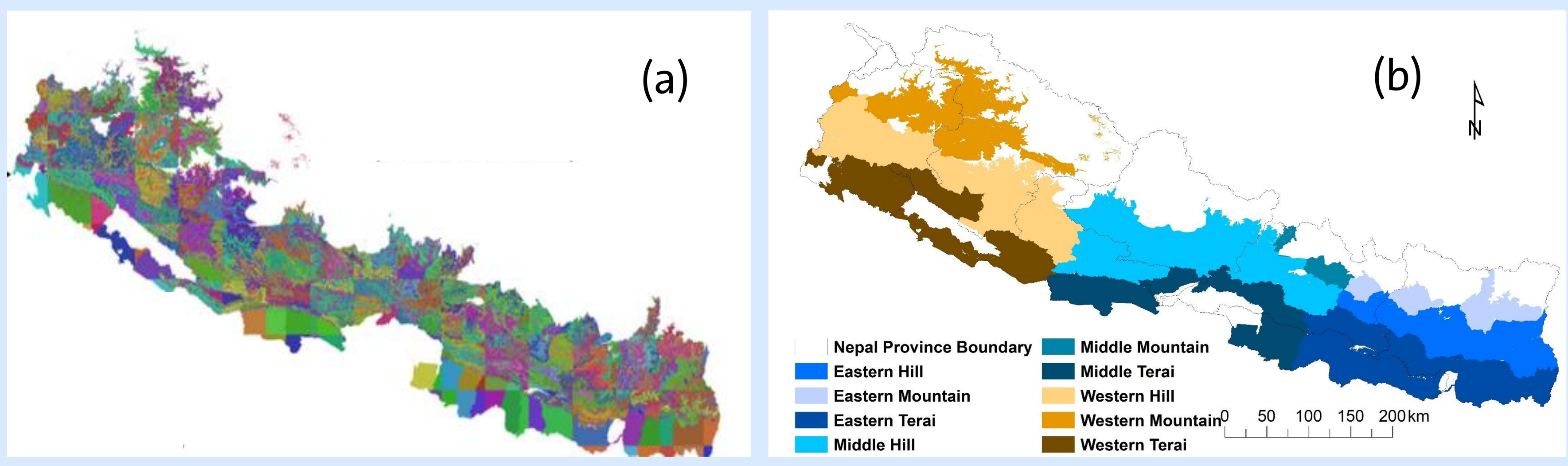

Fig.2. (a) Map of Nepal with the 3430 simulation units, (b) map of Nepal with the nine different ecoregions

WHAT EFFECT DOES INCREASING CANAL CONVEYANCE EFFICIENCY TO 50% HAVE ON INCREASE IN CROP YIELDS?

NEAR FUTURE (2022-2050)

Table 1. Percentage increase in rice crop yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Rice		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	8%	6%	5%
	Middle	12%	9%	7%
	West	11%	8%	8%
Mountain	East	0.1%	0.1%	0.1%
	Middle	1%	0.1%	0%
	West	1%	0.1%	0.1%
Hill	East	0.1%	0.1%	0.1%
	MIddle	4%	4%	3%
	West	1%	0.1%	0.1%

Table 3. Percentage increase in wheat crop yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Wheat		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	0.1%	0.1%	0.1%
	Middle	1%	0.1%	0.1%
	West	1%	0.1%	0.1%
Mountain	East	0%	0%	0.1%
	Middle	0.1%	0.1%	0.1%
	West	0%	0.1%	0.1%
Hill	East	4%	0%	0.1%
	MIddle	0.1%	0%	0.1%
	West	0%	0%	0.1%

Table 5. Percentage increase in maize crop yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Maize		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	17%	11%	10%
	Middle	18%	10%	12%
	West	25%	12%	16%
Mountain	East	9%	0.1%	5%
	Middle	8%	6%	6%
	West	8%	5%	6%
Hill	East	11%	2%	7%
	MIddle	12%	3%	8%
	West	7%	4%	6%

END OF CENTURY (2075-2100)

Table 2. Percentage increase in rice yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Rice		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	10%	11%	13%
	Middle	18%	28%	32%
	West	16%	20%	20%
Mountain	East	0%	0%	0.1%
	Middle	3%	4%	5%
	West	2%	4%	4%
Hill	East	0%	0%	0%
	Middle	18%	5%	9%
	West	11%	2%	4%

Table 4. Percentage increase in wheat crop yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Wheat		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	2%	1%	2%
	Middle	3%	0%	3%
	West	3%	0%	3%
Mountain	East	0%	0%	0.1%
	Middle	0.1%	0.1%	0.1%
	West	2%	1%	4%
Hill	East	44%	21%	0.1%
	Middle	19%	5%	3%
	West	28%	10%	4%

Table 6. Percentage increase in maize crop yields due to increase in CCE from 30% to 50% (mean of three different GCMs)

Maize		SSP1-2.6	SSP3-7.0	SSP5-8.5
Terai	East	13%	12%	9%
	Middle	11%	10%	10%
	West	16%	16%	17%
Mountain	East	0.1%	7%	9%
	Middle	5%	9%	3%
	West	5%	5%	5%
Hill	East	3%	7%	7%
	MIddle	13%	6%	9%
	West	4%	5%	5%

WHAT IS THE MAGNITUDE OF THE EFFECT WITH AN INCREASE TO 70% CCE IN TERMS OF CROP YIELD?

At the end of the century, with a **CCE increase from 30% to 70%**:

- **Rice** yields in the terai will increase up to 2.3 t/ha (59%), in the hill up to 0.9 t/ha (28%), and in the mountain up to 0.4 t/ha (13%).
- **Maize** yields in the terai ecoregion will increase up to 1.17 t/ha (34%), in the hill region up to 0.97 t/ha (22%), and in the mountain region up to 0.71 t/ha (12%).
- **Wheat** yields in the terai ecoregion will increase up to 0. 3 t/ha (7%), in the hill region up to 1.4 t/ha (44%) in and in the mountain region up to 0.3 t/ha (11%).

IMPLICATIONS FOR IRRIGATION PLANNING IN NEPAL

- The targeted increase from 30% to 50% in canal conveyance efficiency can result in **crop yield improvements of 5% to 32%.** Further **increase of up to 59% in crop yields** are possible with 70% efficiency.
- This highlights the need for irrigation system planning to focus on **enhancing conveyance efficiency by at least 50%**, alongside expanding irrigation coverage. However, the role of fertilizer in increasing crop yields cannot be neglected and must also be taken into account (Basukala & Rasche, 2022).
- This efficiency increase is achieved by **upgrading irrigation infrastructures, lining canal, regular maintenance, silt removal and cleaning the canals** .
- Towards the end of the century, the benefits of improved canal conveyance are even more substantial for rice and wheat compared to the near future, emphasizing the **long-lasting impact of investments** on improving effieciency but for maize the current improvement will be more beneficial.
- The crop yield increase are especially pronounced in the **terai region** thus this area **must be highly prioritized** when investing into enhanced irrigation systems followed by **hilly regions**.

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