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Additional information
Supplementary information is available in the online version of the paper.

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CORRESPONDENCE:

Climate adaptation in India

To the Editor — The United Nations Framework Convention on Climate Change (UNFCCC) has established the green climate fund, the adaptation fund and the fund for least developed countries (LDCs) to support developing countries and LDCs in their efforts to adapt to climate change. However, accessing these funds is challenging mainly because the interested countries have limited technical capacity to prepare effective proposals for fund applications. Further adaptation is not easily measurable, which makes it difficult to disburse the funds in a transparent, equitable and efficient manner. The 17th conference of the parties to the UNFCCC established the National Adaptation Plan (NAP) process as a way to facilitate effective adaptation planning in LDCs and developing countries. NAPs should reduce vulnerability to the impacts of climate change, by building adaptive capacity and resilience, and should facilitate the integration of climate change adaptation in the countries' plans for economic development.

At present, India is implementing the State Action Plan on Climate Change (SAPCC) — a set of strategies for adaptation and mitigation at the subnational and local level. In terms of adaptation, the SAPCC is like a NAP that operates at the local level. Many state governments have initiated the SAPCC, thanks to the technical and financial support from multilateral development agencies. The estimation of the costs of implementing the SAPCC is cumbersome. A study has observed that existing estimates of costs for both adaptation and mitigation, which are in the range of US$3–5 billion over a five-year period for states of similar size and climate change challenges, are inconsistent mainly because of variation in the methodologies adopted for vulnerability assessment, development of adaptation plans and mitigation targets[1]. As the UNFCCC has not standardized the procedure for vulnerability assessment, preparation of adaptation plans and estimation of adaptation costs, the difficulties with the SAPCC are likely to reverberate in the national action plans of many developing countries and LDCs.

The SAPCC operates locally and, with a typical bottom-up approach, helps to build resilience at the national level. Hence, it is fundamental for local communities to understand their vulnerabilities to climate change and get involved in the adaptation planning[2]. Lessons should be learned from existing schemes in India — such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) — that aim at decentralized governance and empowering local institutions and that have already generated success stories[3]. Like the MGNREGA scheme, the SAPCC could be taken a step further and involve local governing institutions in the preparation of the local adaptation plan, even on a microscale such as districts and blocks, with support from scientific communities, given the importance of including local knowledge in adaptation planning[4]. After translating the SAPCC into workable local adaptation programmes, two steps are required. One is capacity building of stakeholders, mainly members of local governing institutions and government officials. The other is addressing hard adaptation initiatives — those that, according to the World Bank, usually imply the use of specific technologies and actions involving capital goods (infrastructure) as opposed to soft adaptation that focuses on information, capacity building, policy and strategy development, and institutional arrangements.

Once local challenges are understood, the adaptation process needs to move towards measurement and planning. The key measures here are the vulnerability of the region and the capacity of stakeholders to efficiently implement the adaptation project[5]. In the case of soft adaptation, financial support will have to be used to train local government body representatives and line department officials. This training may comprise vulnerability assessment methodology, assessing adaptive capacity and exposure to good practices on adaptation. With this training, the stakeholders must be able to develop and implement an appropriate adaptation plan for the region.

Measuring adaptation is difficult, but as vulnerability is a function of adaptive capacity, it may be used as an indicator to measure success of adaptation. A number of publications and indicators on vulnerability assessment are now available[6]. However, fixing benchmarks for vulnerability assessment universally is difficult, owing to uncertainty in indicators[7]. This makes it difficult to standardize the disbursement of funds for hard adaptation, given varying vulnerability assessment techniques, as well as geographically and socio-economically varying adaptation needs and costs. Overall, the implementation of NAPs such as the SAPCC in India will succeed only if the local stakeholders are adequately trained and the preparation of adaptation plans is done in a participatory manner. The UNFCCC and other adaptation funding agencies must first set up funds for soft adaptation, such as capacity building of key stakeholders[8], then develop a standard procedure for baseline vulnerability assessment and estimation of adaptation costs across developing countries and LDCs, for equitable and efficient allocation of funds. Hopefully, the example of the SAPCC in India will help LDCs and developing countries in local adaptation planning and to access global funds, should the SAPCC succeed in obtaining them. ❐

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Temperature and drought effects on maize yield

To the Editor — In their statistical analysis of temperature and rainfall effects on maize yield, Lobell *et al.* concluded[1] that excessive temperature above 30 °C during the June–August period contributed more significantly to lowering yields in the US corn belt than did the total rainfall during the same period. The authors used yield simulations from a process-based model (Agricultural Production Systems Simulator, APSIM) to verify their statistical conclusions. For reasons we outline below, we believe that these conclusions can be misleading because the major and consistent cause of rain-fed maize yield reductions in the humid and sub-humid US corn belt is the prolonged absence of significant rainfall and the resulting soil-water deficit.

First, we question the conclusion of Lobell *et al.* that rainfall during growing season (June–August) is less important in maize yield reduction than higher temperatures[1]. Their analysis of the observed data used in the study does not take into account either rainfall distribution or the rainfall not available to the crop due to surface runoff, drainage or soil evaporation. Furthermore, water stored in the soil profile at the beginning of June, should supply 150 to 180 mm of water available for transpiration — over a month's supply of water without any more rainfall. This initial soil-water supply added to the approximately 300 mm average rainfall occurring during the June–August period (Fig. 1b in ref. 1), even with a decrease of 20%, should have little influence on yield, as confirmed by their model analysis.

Secondly, use of constant transpiration efficiency (TE) in APSIM when normalized with vapour-pressure deficit (VPD) leads to biases in transpiration at high VPD. This is confirmed by the unrealistically high values of transpiration demand reported in Fig. 2c of ref. 1 (15 mm per day on apparently clear and hot days), two to three times higher than the potential evaporation calculated with commonly used and field-tested combination equations for humid and sub-humid climates like that of Iowa (Table 1).

Table 1 | Potential evapotranspiration (PET) at various vapour-pressure deficit (VPD) values as calculated with APSIM and with the Penman combination equation used by the Midwestern Regional Climate Center for Central Iowa.

T_{min}	T_{max}	VPD	APSIM	Penman
15	26	1.28	5.67	4.43
16	28	1.47	6.54	4.58
17	30	1.69	7.51	4.73
19	32	1.94	8.60	4.87
20	34	2.21	9.82	5.00
22	36	2.51	11.17	5.12
23	38	2.85	12.68	5.24
24	40	3.23	14.34	5.36

Assumptions for APSIM: 40 g m^{-2} growth, VPD is 0.75 times the difference between saturated vapour pressures at the maximum and minimum temperatures; for Penman: wind speed 1.5 m sec^{-1} and 15 MJ m^{-2} net radiation (about 55% of clear day mid-summer solar radiation). The saturated VPD equation published in ref. 1 omitted the multiplier 0.6112.

Constant normalized TE as used in APSIM is based on cell-level arguments and does not take into account whole canopy dynamics. We have shown that measured canopy TE varies considerably with management and soil cover at the same site, thus having no need for VPD normalization[2]. We are not aware of any tests of the APSIM model under field conditions in the literature that show evapotranspiration (ET) values in the 12 to 15 mm per day range as reported in the simulations in Fig. 2c of ref. 1. A recent paper[3] with maize ET values measured in the field at several sites in Iowa indicated maximum values of about 5 mm per day.

In conclusion, we believe that the influence of larger VPD resulting from higher temperatures as the cause of yield decreases is overstated and that soil-water deficit is the major and consistent reducer of yields, but that it cannot be reasonably described using seasonal rainfall alone. Extremely high temperatures are induced by drought[4], which significantly affects maize yield as in 1983, 1988 and 2012; all years having many more 'extreme degree days' greater than 37 °C than other years in central Iowa since 1961. But in many regions of the world, including the Midwest US, drought can still occur regardless of temperature. ❐

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