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# Assessing Sweet Sorghum-based Ethanol Potential within Water-Energy-Food Nexus Framework in China

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## Background

Biofuels have received worldwide attention as important energy alternatives, and bio-ethanol plays a significant role in biofuels development. Sweet sorghum is one of the most important bio-ethanol feedstock because of high levels of sugars in its stalks and great tolerance to abiotic stresses. However, it is found that planting sweet sorghums may lead to increased usage of water, so that marginal lands under great water stress are not suitable for planting sweet sorghums. Water, energy and food are all fundamental natural resources for sustainable development, and FAO, UNESCAP, etc. are trying to establish the Water-Energy-Food nexus (WEF nexus) framework. Under these circumstances, evaluating sweet sorghum-based ethanol potential under WEF nexus frameworks is of great necessity.

## Methods

### Water-Energy-Food nexus framework

We introduced bio-ethanol as an essential element into WEF nexus framework for sweet sorghum-based ethanol potential assessment in China, shown as Fig.1. Energy and water are two basic factors that drives bio-ethanol production, from feedstock growing stage to bio-ethanol fermentation and combustion stages, whereas bio-ethanol is an important energy alternative for fossil fuels. Additionally, bio-ethanol and food factors may conflict with each other because they compete for lands for cultivation.

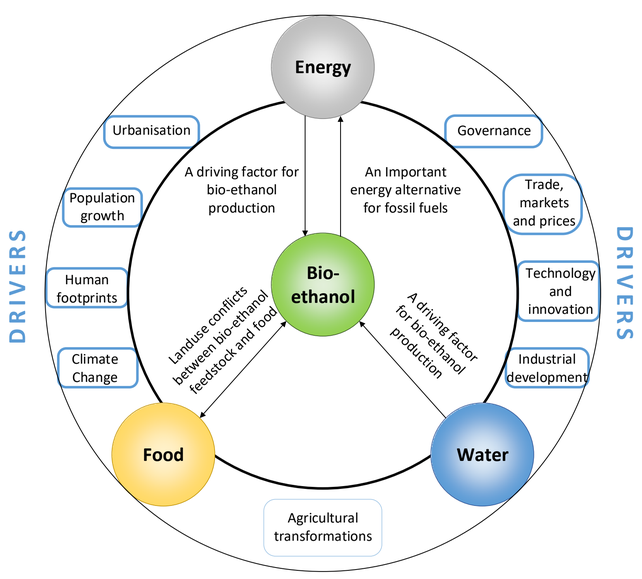



*Fig.1 Bio-ethanol and its interactions with WEF nexus*

### Life Cycle Assessment

Water consumption, GHG (Greenhouse Gas) emissions, and the net energy gain potential of sweet sorghum-based ethanol on marginal land in China were assessed using life cycle assessment method. Five stages of over the life cycle of bio-ethanol were included. The flowchart of system boundary of life cycle assessment is shown in Fig.2.

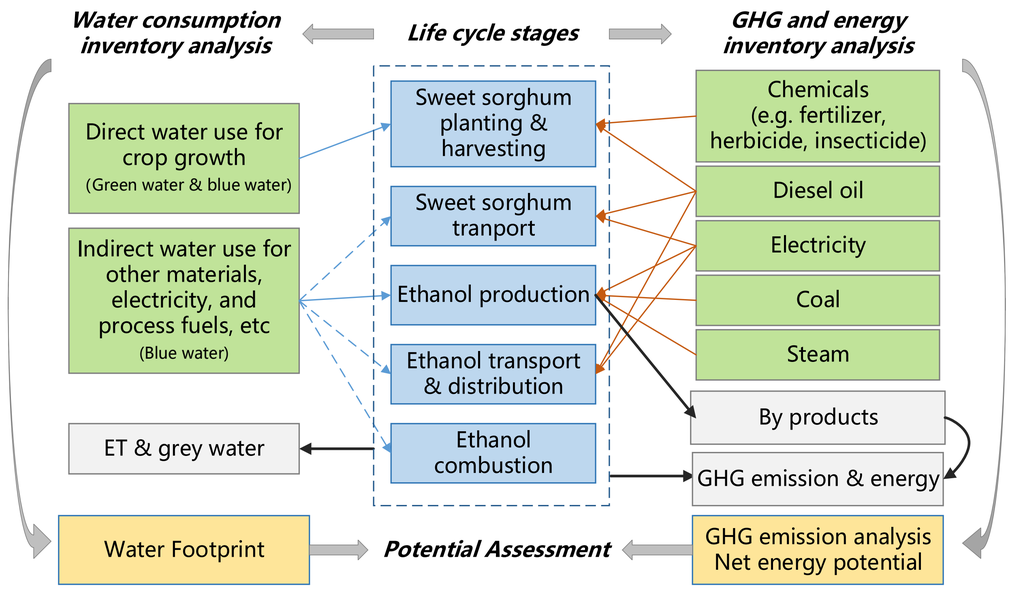
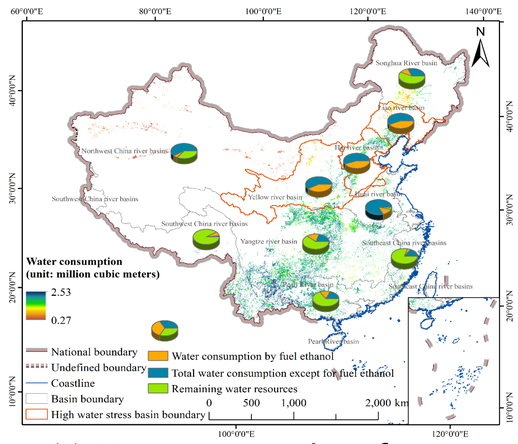
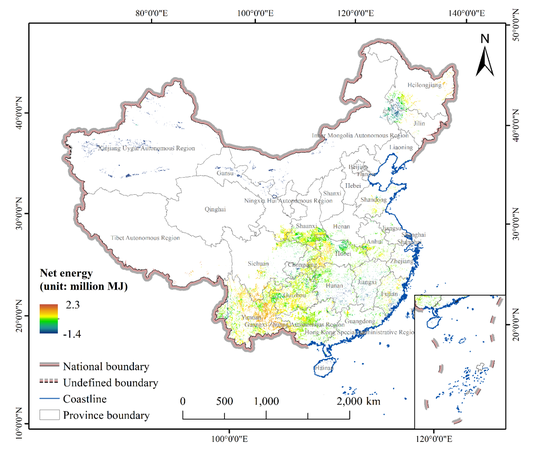



*Fig.2 System boundary of life cycle assessment. Solid blue arrows show the input water flows that are considered, whereas dashed blue arrows show the input water flows that are not considered in this paper; brown arrows show the input flows of materials and energy; and black arrows show the output flows of water, GHG and energy.*

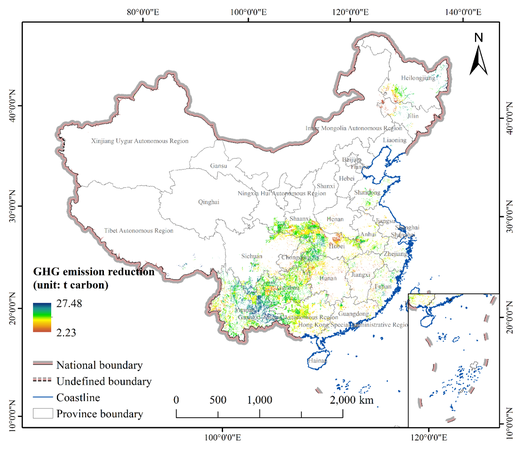
## Results



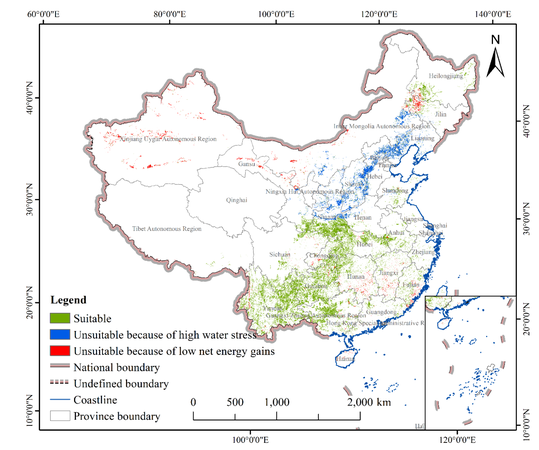

*(a) Water consumption of sweet sorghum-based ethanol*




*(b) Net energy gain of sweet sorghum-based ethanol*




*(c) GHG emission reduction of sweet sorghum-based ethanol*




*(d) The suitability analysis of marginal lands for sweet sorghum-based ethanol development*

- **The water consumption** of sweet sorghum-based ethanol in China was predicted at 348.95 billion $m^3$;
- **The net energy gain** was assessed at 182.62 billion MJ per year;
- **The GHG emissions reduction** potential was estimated at 2.47 million tons of carbon per year, equivalent to the GHG emissions caused by 286,000 tons of petrol per year;
- **26.72%** of the marginal lands in China is assessed not suitable for sweet sorghum-based ethanol development.

## Conclusions

Even though 26.72% of the marginal lands in China was assessed not suitable because of high water pressure and low net energy gains, Southern China showed net energy gain and GHG emission reduction potentials. Policy makers can give some priority of sweet sorghum-based ethanol development to these regions such as Yunnan Province, Guangxi Zhuang Autonomous Region, Hubei Province and the southern part of Shaanxi province, which showed higher net energy gain and GHG emission reduction potential than other regions.

## Acknowledgments

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