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RESEARCH ARTICLE

China's Agriculture Green Development: from Concept to Actions

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Supplemental materials

Table S1 AGD indicators grading guidelines

Number	Indicators	Directions[#]	Grading Criteria	Reference
1.1.1	Veterinary input	-	This indicator evaluates the level of veterinary drug use in the livestock industry. Based on the average investment in veterinary drugs per standard animal (dairy cow) in China (122 yuan·LU^{-1}·yr^{-1}) in 2018. We classify levels I–IV standard to be > 244 yuan·LU^{-1}·yr^{-1}, 122–244 yuan·LU^{-1}·yr^{-1}, 61–122 yuan·LU^{-1}·yr^{-1}, and < 61 yuan·LU^{-1}·yr^{-1}	[1]
1.1.2	Pesticide input	-	This indicator evaluates pesticide use in agricultural production. China's national statistics show a total amount 1.5036 million tons pesticides input in 2018 (equivalent to 9.95 kg·ha^{-1}). Currently, the average pesticide input in Europe and the United States is 2.5 kg·ha^{-1}. Therefore, the levels I–IV standards are set to be >10 kg·ha^{-1}, 5–10 kg·ha^{-1}, 2.5–5 kg·ha^{-1}, and < 2.5 kg·ha^{-1}	[2]
1.1.3	Exogenous N input in animal feed	-	This indicator reflects the coupling between crop and livestock production. In a perfect situation, all nitrogen inputs in livestock production should come from crop production with no external nitrogen demand for feed. Therefore, the levels I–IV standards are set to be all (> 120 kg), 50% (60–120 kg), less than 50% (0–60 kg), and zero (⩽ 0 kg) nitrogen inputs per year in livestock production are from external sources	[3]

1.1.4	Agricultural water footprint	-	This indicator reflects the consumption of water resources. China's per person water footprint for food consumption as 561–679 $m^3 \cdot person^{-1}$. The United Nations recommends that China's water footprint needs to reduce by 22.5% (480 $m^3 \cdot person^{-1} \cdot yr^{-1}$) to achieve equal consumption of global water footprint. Therefore, the levels I–IV standards, based on the national average and the target value, are > 760, 620–760, 480–620, and < 480 $m^3 \cdot person^{-1} \cdot yr^{-1}$	[4]
1.2.1	Cropland protein productivity	+	This indicator measures the productivity of agricultural production. Protein yield per unit land in China was 313 $kg \cdot ha^{-1}$ in 2020. Research has shown the yield of major grain crops can increase by 1.48 times (431 $kg \cdot ha^{-1}$, compared to 2005) with an 80% of the yield potential realized. Therefore, the levels I–IV standards for this indicator are < 313, 313–372, 372–431, and > 431 $kg \cdot ha^{-1}$	[2]
1.2.2	Cropland calorie productivity	+	This indicator measures the productivity of agricultural production. With an 80% achievement of the yield potential, China's unit land calorie yield would increase from 1961 × 10^4 $kcal \cdot ha^{-1}$ to 2399 × 10^4 $kcal \cdot ha^{-1}$. Therefore, the levels I–IV standards are: < 1960, 1960–2180, 2180–2400, and > 2400 (× 10^4 $kcal \cdot ha^{-1}$)	[2]
1.2.3	Cropland economic productivity	+	This indicator evaluates the economic return from agricultural production. The level IV standard set an aim for 80% of economic return of agriculture in Japan and the Netherlands, which is 80% × (149,000 + 114,000) / 2 = 105,000 $yuan \cdot ha^{-1}$, Level III 84,200, Level II 67,300, and Level I < 67,300 $yuan \cdot ha^{-1}$	[5]
1.2.4	Irrigation efficiency	+	This indicator measures the irrigation efficiency. Proportion of irrigation water entering farmland. The Comprehensive National Water Resources Plan demands irrigation efficiency should increase to 0.6 by 2030. Therefore, the levels I–IV standards were assigned as < 0.5, 0.5–0.55, and 0.55–0.6, and > 0.6	[6]
1.3.1	Energy use efficiency	-	This indicator evaluates the dependence of agricultural production on energy. The China's 12th Five-Year Plan and 13th Five-Year Plan suggests a reduction of 22.5% of current energy consumption per unit of output value (7291 $MJ \cdot (10{,}000\ yuan)^{-1}$). Based on this goal, the levels I–IV standards are > 7291, 6197–7291, 5650–6197, and < 5650 $MJ \cdot (10{,}000\ yuan)^{-1}$	[7]
1.3.2	Cropland nitrogen use efficiency	+	This indicator evaluates the nitrogen efficiency in agricultural production. European countries has achieved a 65% NUE (best in the world), the United States has reached 50%, and China has reached 35%. Therefore, the levels I–IV standards for this indicator are 0%–35%, 35%–50%, 50%–65%, and > 65%	[8]
1.3.3	Animal nitrogen use efficiency	+	This indicator measures the nitrogen utilization in livestock production. The current nitrogen utilization rate in China's livestock industry is approximately 7.6%. With the top 5 provinces have reached an average of 30%, the levels I–IV standards are < 10%, 10%–20%, 20%–30%, and > 30%	[9]
1.3.4	Phosphorus use efficiency	+	This indicator measures the phosphorus efficiency in agricultural production. From 1980 to 2020, the average PUE in China was 40% (ranging from 33% to 59%). Therefore, the levels I–IV standards are 0%–20%, 20%–30%, 30%–40%, and > 40%	[9]
2.1.1	Agricultural investment	+	This indicator measures government financial support for agricultural development. In 2018, China's expenditure on agriculture, forestry, and water resources was 3739 $yuan \cdot person^{-1}$, and it ranged from 2158 to 9657 $yuan \cdot person^{-1}$ in the main agricultural provinces. We then use <3259, 3259–4786, 4786–6140, and > 6140 $yuan \cdot person^{-1}$ as the standards for the levels I–IV, which grading by reference to the quartering method	[10]
2.1.2	Mechanization	+	This indicator evaluates agricultural mechanization. By the end of 2018, the unit mechanization power of cultivated land in major agricultural provinces ranged from 3.6–13.9 $kw \cdot ha^{-1}$. The levels I–IV standards are < 6.2, 6.2–8.4, 8.4–11.5, and > 11.5 $kw \cdot ha^{-1}$	[11]

2.1.3	Farmers' education	+	This indicator evaluates the level of education among rural population. The national compulsory education program has been widely implemented over the past few decades. We assume that the proportion of population with a high school education or above should exceed 90% to meet the IV level standard. Based on the equal division method, the grading standards for levels I–IV are 0%–22.5%, 22.5%–45%, 45%–90%, and > 90%	[12]
2.1.4	Irrigation coverage	+	This indicator measures the state of irrigation equipment in agricultural production. From 1997 to 2020, the proportion of effective irrigated area in China increased from 39% to 56%. This indicator assumes 70% to be the IV level standard, 60% to be the IV level standard 70% for level III, 50%–60% for level II, and less than 50% for level I	[13]
2.1.5	Land transfer	+	This indicator evaluates land transfer and concentration in China. We assumed for an 80% of arable land transfer to be the IV level standard for this score. Therefore, the national proportion of land transfer should reach 57.7%. Based on this, the I–IV level standards for this indicator are < 20%, 20%–40%, 40%–60%, and > 60%	[14]
2.2.1	Income equality	-	This indicator evaluates the income gap between urban and rural residents. Some developed countries, such as Japan and the Netherlands, have eliminated the income gap between urban and rural areas. Currently, the urban–rural income ratio in most countries is less than 1.6. We assume the I–IV level standards to be > 2.0, 1.6–2.0, 1.2–1.6, and < 1.2	[15,16]
2.2.2	Farmer income	+	This indicator evaluates income level of farmers. We adopt the latest World Bank per person income classification to be the I–IV level standards. That is, 0–7175 yuan·person^{-1} (Level I, low income), 7175–27,972 yuan·person^{-1} (Level II, lower-middle income), 27,972–86,625 yuan·person^{-1} (Level III, upper-middle income), and above 86,625 yuan·person^{-1} (Level IV, high-income)	[17]
2.2.3	Agricultural income	+	This indicator evaluates the contribution of agricultural production to farmers' income. In China, the average value in 2020 was 37%, and based on this, the I–IV level standards are analyzed and divided into 0%–10%, 10%–20%, 20%–40%, and > 40%	*
2.3.1	Animal-derived food consumption	+	This indicator evaluates the matching degree between agricultural production supply and residents' dietary needs. Chinese Dietary Guidelines (2016) recommended daily intake of protein for 59.7g·d^{-1} (45.5–73.9 g·d^{-1}), of which animal protein accounts for 34.1g·d^{-1} (27.8–40.3 g·d^{-1}), a proportion of 54.5%–61.5% protein intake from animal product. Therefore, we assume the I–IV level standards to be 0%–20%, 20%–40%, 40%–55%, and > 55%	[18,19]
2.3.2	Protein intake	+	This indicator evaluates the dietary nutrition status. According to the Chinese Dietary Guidelines (2016), the National Health Commission, and the World Health Organization, an appropriate protein intake should be between 50–65 g·d^{-1}. Therefore, we assume the levels I–IV standards to be < 14.6 or > 34.7, 14.6–18.3 or 29.2–34.7, 23.7–29.2, and 18.3–23.7	[19]
3.1.1	Animal waste recycling	+	This indicator assesses the utilization of livestock manure. The China's Official Document Opinions on Innovating System Mechanisms and Promoting AGD requires the utilization rate of livestock waste to reach 75% by 2030. The levels I–IV standards are set as < 35%, 35%–55%, 55%–75%, and > 75%	[20]
3.1.2	Crop residues recycling	+	This indicator assesses the utilization of straw. The same document (as in 3.1.1) requires comprehensive utilization rate of straw to reach 85% by 2030. The levels I–IV standards are set at < 45%, 45%–65%, 65%–85%, and > 85%	[20]
3.1.3	Plastic film recycling	+	This indicator assesses the recycling and utilization of agricultural plastic film. The same document (as in 3.1.1) requires agricultural film recycling rate to reach 80% by 2030. The levels I–IV standards are set at as < 40%, 40%–60%, 60%–80%, and > 80%	[20]

3.2.1	Crop-livestock system N surplus	-	This indicator assesses nitrogen input and environmental pressure. Studies show that the appropriate nitrogen surplus should not exceed 90 kg·ha^{-1}. The corresponding levels I–IV standards are > 270, 180–270, 90–180, and < 90 kg·ha^{-1}	[21]
3.2.2 3.2.3	Soil erosion[1] Soil erosion[2]	-	This indicator reflects the degree of soil erosion, which refers to the amount of soil erosion and displacement that occurs on the surface soil per unit area and unit time. We refer to the national standards for soil erosion as the levels I–IV standards, which is > 5000, 2500–5000, 500–2500, and < 500 t·km^{-2}·yr^{-1}. When missing the above data, percentage land of soil erosion is used as an alternative indicator for assessing soil erosion. This indicator is graded as > 30%, 20%–30%, 10%–20%, and < 10%	[22,23]
3.2.4	Animal carrying capacity	-	This indicator evaluates the matching degree between crop and livestock production in terms of absorbing and utilizing animal manure. The document (as in 3.1.1) suggests for a 50% of the nitrogen fertilizer source comes from livestock manure in the crop production, indicating an optimal situation of 2.7 heads·ha^{-1} (standard dairy cow). Therefore, the levels I–IV standards are > 2.7, 1.9–2.7, 1.1–1.9, and < 1.1 LU·ha^{-1}	[24]
3.3.1	Surface water quality	+	This indicator evaluates the surface water quality. The levels I–IV standards refers to China's National Standard for Surface Water: < 50%, 50%–70%, 70%–90%, and > 90% should be qualified for the national standards	[25]
3.3.2	Groundwater quality	-	This indicator evaluates the groundwater quality. The levels I–IV standards refers to China's National Standard for Groundwater (GB/T 14848): > 50%, 30%–50%, 10%–30%, and < 10%	[26]
3.3.3	Soil pesticide pollution	-	This indicator measures pesticide pollution in farmland soil. The levels I–IV standards refers to the National Soil Environmental Quality Standard (GB15618-2018): > 10%, 5%–10%, 2%–5%, and < 2%	*
3.3.4	Soil heavy metal pollution	-	This indicator assesses heavy metals pollution in farmland soils. The levels I–IV standards refers to the National Soil Environmental Quality Standard (GB15618-2018): > 10%, 5%–10%, 2%–5%, and < 2%	*
3.3.5	Air quality	-	This indicator assesses the air pollution situation. The levels I–IV standards refers to the National Environmental Air Quality Standard (GB3095-2012), that the number of days when API exceeds 100 within a year should not exceed > 30, 20–30, 10–20, or < 10 d.	[27]
3.4.1	Ammonia emission	-	This indicator evaluates the ammonia emission from farmland. The current ammonia emission per unit of arable land in China is 128 kg·ha^{-1}. According to environmental safety standards, China should reduce ammonia emission by 0%–40%. We assumes a 20% reduction to be the optimal situation, and the corresponding levels I–IV standards are > 140, 120–140, 100–120, and < 100 kg·ha^{-1}	[28]
3.4.2	N use efficiency in food system	-	This indicator evaluates the nitrogen efficiency in the food system (the amount of nitrogen emitted to the environment per kilogram of food produced). Studies show that the nitrogen cost of grain production in the United States is about 1.4 kg·kg^{-1}, while the nitrogen cost of producing livestock products is about 4.8 kg·kg^{-1}. Therefore, using 50% plant nitrogen and 50% animal nitrogen as the IV level standard, the I–IV level standards for this indicator are > 5, 4–5, 3–4, and < 3 kg·kg^{-1}.	[29,30]
3.4.3	GHG emissions	-	this indicator evaluates agricultural greenhouse gas emissions. According to FAO, GHG emissions from agriculture is 3656 kg·ha^{-1} CO_2-eq world average, 4817 kg·ha^{-1} CO_2-eq in France, 3776 kg·ha^{-1} CO_2-eq in Germany, 8511 kg·ha^{-1} CO_2-eq in the United States, and 4686 kg·ha^{-1} CO_2-eq in Japan. Accordingly, we set the levels I–IV standards as > 6500, 5000–6500, 3500–5000, and < 3500 kg·ha^{-1} CO_2-eq.	[31]

[#]Note: (+) symbolizes a positive indicator, higher is better; (-) symbolizes a negative indicator, lower is better, * symbolizes the Grading Criteria is made in this research.

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