

Table S1. Formulas and parameters of N flow in apple supply chain

Process	Items	Formula	Parameter meaning	Data source
Production process	N _{input}	Chemical fertilizer (I_1)	$I_1 = F_1 * C_1$ F_1 : Chemical fertilizer application; C_1 : N content in chemical fertilizer	Survey data, calculation
		Manure (I_2)	$I_2 = F_2 * C_2$ F_2 : Manure application; C_2 : N content in manure	Survey data, calculation
		Biological fixed (I_3)	I_3 I_3 =Amount of farmland biological N fixation in Hebei province/farmland area in Hebei province	Xiang, R. et al, 2013 ^[32] ; Department of Natural Resource of Hebei Province, 2018
		Deposition (I_4)	I_4 I_4 =25.8 kg(N)·hm ⁻² ·a ⁻¹	Institute of Geographic Sciences and Natural Resources Research, CAS, 2016
		Irrigation (I_5)	$I_5 = S * C_3$ S : Average irrigation capacity, 4705.70 m ³ ·hm ⁻² ·a ⁻¹ ; C_3 : N from irrigation water, 3.78 mg·L ⁻¹	Cao, C. 2014; Chen, Y. 2013 ^[33,34]
	N _{output}	Apples (O_1)	$O_1 = Y' * C_4$ C_4 Y' : Apple yield C_4 : N content of apple fruit, 5.37 g·kg ⁻¹	Survey data Fan, H. et al, 2008 ^[35]
		Trees (O_2)	$O_2 = 248.95 * C_5$ O_2 : N accumulation of apple tree, and the value of N accumulation of one tree is 248.95 g; C_5 : Density, unit: plant·hm ⁻²	Fan, H. et al, 2008 ^[35]
		NH ₃ (E_1)	E_1 E_1 : The percentage of NH ₃ volatilized N loss in the amount of N applied; 50% Chemical fertilizer +50% manure: 3.48%, 75% Chemical fertilizer +25% manure: 4.1%	Ge, S. 2011 ^[36]
	N _{loss}	N ₂ O (E_2)	E_2 E_2 : The percentage of denitrification loss in the amount of N applied, 0.81%	Ge, S. 2011 ^[36]
		Others (E_3)	E_3 E_3 : Other N loss, 47.49%	Ge, S. 2011 ^[36]
		Residue (E_4)	E_4 $E_4 = I_1 - O_1 - O_2 - E_1 - E_2 - E_3$	
Sales process	N _{input}	Apple (O_1)	Same as above	
	N _{output}	Retail (O_3)	$O_3 = (O_1 - E_5) * 30\%$ O_3 : The N content of retail apples, accounting for 30% of apple sales	Survey data, calculation
		Acquisition (O_4)	$O_4 = (O_1 - E_5) * 50\%$ O_4 : The N content of acquisition apples, accounting for 50% of apple sales	Survey data, calculation
		Picking garden (O_5)	$O_5 = (O_1 - E_5) * 10\%$ O_5 : The N content of picking garden apples, accounting for 10% of apple sales	Survey data, calculation
		Others (O_6)	$O_6 = (O_1 - E_5) * 5\%$ O_6 : The N content of apples sold by other ways, accounting for 5% of apple sales	Survey data, calculation
	N _{loss}	Non-commerical fruits (E_5)	$E_5 = O_1 * R$ C_4 : N content of apple fruit, 5.37 g·kg ⁻¹ ; R : Bad fruit rate, 5%	Survey data, calculation

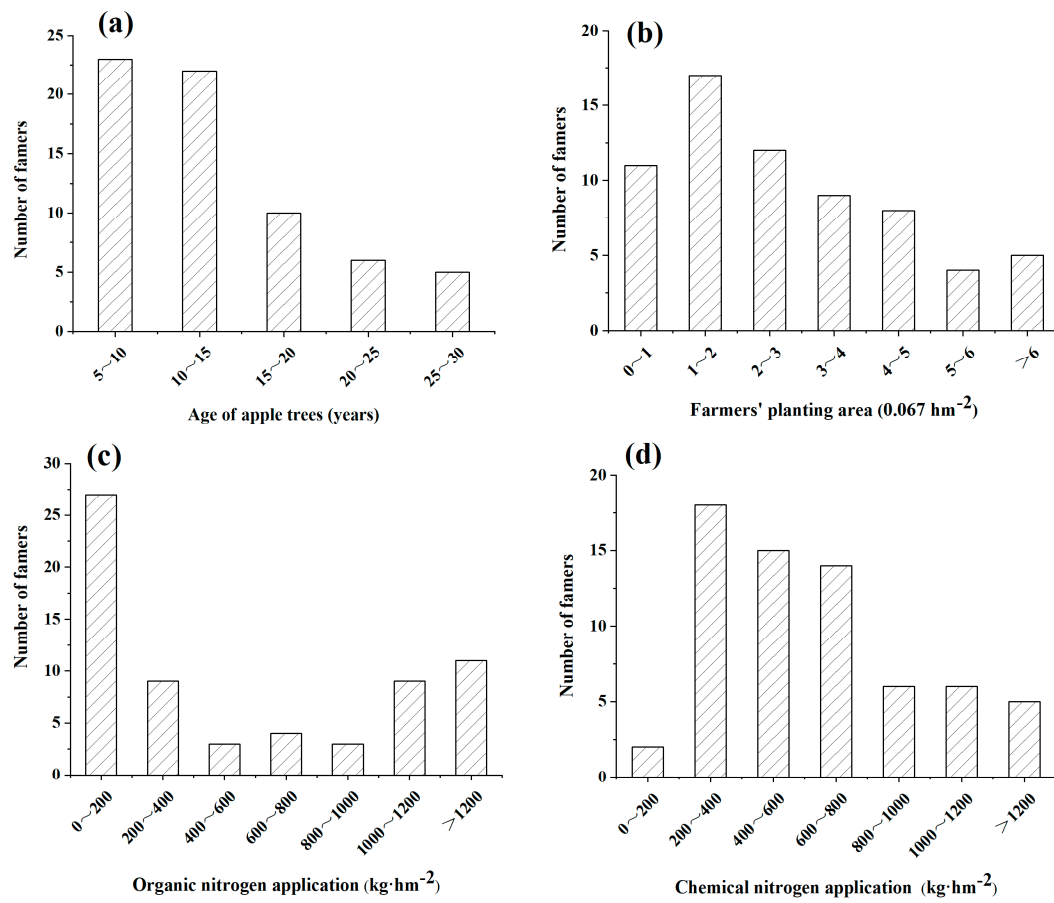


Figure S1. Distribution of basic characteristics of apple producers in QuZhou. (a) Age of apple trees; (b) Farmers' planting areas; (c) The amount of organic nitrogen used by smallholders; (d) Nitrogen application rate of chemical fertilizers to smallholders.