Supplementary Material

* 1. Supplementary Figures



Supplementary Figure 1. The schedule for cultivating 9 types of vegetables by farmers in the Erhai Lake Basin (sowing and harvesting stages).

 Supplementary Figure 2. Global warming potential (A), eutrophication potential (B), acidification potential (C), and energy depletion (D) of different vegetable production systems. Each environment impact is influenced by the agricultural materials stage (MS) and the farming stage (FS). MS includes the production and transportation of structural materials, fertilizers, pesticides, and the fuel used for machinery. FS includes the application of fertilizers and pesticides and the use of fuel for machinery.

 Supplementary Figure 3. Contributions of inputs to the global warming potential (A), eutrophication potential (B), acidification potential (C), and energy depletion (D) of different vegetable production systems. Each environment impact is influenced by the agricultural materials stage (MS) and the farming stage (FS). MS includes the production and transportation of structural materials, fertilizers, pesticides, and the fuel used for machinery. FS includes the application of fertilizers and pesticides and the use of fuel for machinery.

Supplementary Figure 4. Relationships among environmental impacts, fertilizer inputs, vegetable yields, PFP-N, NEEB, and EB among different vegetables production systems on per ton of vegetables production. The environmental impacts include the global warming potential, eutrophication potential, acidification potential, and energy depletion potential.



Supplementary Figure 5. Uncertainty analysis of environmental impacts (A, B, C, D) and NEEB (E).



Supplementary Figure 6. Sensitivity analysis for impact factors of environmental impacts and economic benefits.

1.2 Supplementary Tables

Supplementary Table 1. Basic background information of the surveyed farmers.

|  |  |  |
| --- | --- | --- |
| Respondent information | Mean | Range |
| Age of decision-makers | 52.2±8.9 | 32-75 |
| Years of education (yr) | 8.7±5.0 | 0-17 |
| Annual household income ($ yr-1) | 9455±7709 | 1450-46394 |
| Total planting area (ha) | 1.4±2.3 | 0.07-13.3 |
| Number of agricultural labor | 2.3±1.4 | 1-7 |
| Planting experience (yr) | 27.3±13.1 | 2-55 |

Supplementary Table 2. The planting area of the nine vegetables in this study for the year 2022.

|  |  |
| --- | --- |
| Vegetables | Planting areas (ha-1) |
| Asparagus Lettuce | 690 |
| Green Onion | 219 |
| Radish | 292 |
| Chinese Cabbage | 374 |
| Green | 372 |
| Spring Onion | 377 |
| Cabbage | 437 |
| Pepper | 2539 |
| Eggplant | 111 |

Supplementary Table 3. Agricultural inputs for the production of each vegetable in this study area.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Inventory | Unit | Asparagus Lettuce | Green Onion | Radish | Chinese Cabbage | Greens | Spring Onion | Cabbage | Pepper | Eggplant |
| Plastic film | kg ha-1 | 79.2±29.0 | 0 | 69.4±7.18 | 72.2±29.8 | 30.6±32.8 | 20.8±30.6 | 68.4±6.26 | 50.9±21.3 | 151±29.8 |
| Electricity | kWh ha-1 | 342±278 | 360±40.2 | 180±4.08 | 303±202 | 230±107 | 499±439 | 180±2.67 | 178±9.82 | 208±79.6 |
| Machinery | h ha-1 | 41.4±27.5 | 80.0±7.75 | 30.0±1.63 | 36.5±21.6 | 52.5±26.0 | 102±59.1 | 30±1.07 | 47.2±20.4 | 30.0±1.07 |
| Diesel | kg ha-1 | 107±35.9 | 146±10.6 | 87.0±1.63 | 93.8±20.4 | 105±29.9 | 168±65.9 | 87±1.07 | 106±24.8 | 87.0±1.60 |
| Insecticide | kg ha-1 | 3.56±2.98 | 3.59±0.44 | 3.15±0.150 | 3.88±3.42 | 1.97±0.66 | 1.79±1.67 | 2.59±1.30 | 0.552±0.051 | 3.15±0.08 |
| Fungicide | kg ha-1 | 4.48±3.05 | 4.20±0.470 | 0.48±0.02 | 3.65±2.05 | 4.05±3.20 | 1.64±1.30 | 2.51±1.16 | 0.46±0.036 | 0.48±0.011 |
| Herbicide | kg ha-1 | 1.58±0.334 | 1.90±0.182 | 1.88±0.075 | 1.91±0.184 | 1.91±0.075 | 1.31±0.512 | 1.88±0.106 | 1.36±0.031 | 1.93±0.325 |
| Labor | h ha-1 | 2742±314 | 1842±195 | 1539±308 | 1823±236 | 1166±117 | 1539±286 | 1684±74.3 | 3620±869 | 1672±142 |

Supplementary Table 4. Main pollutant emissions factors of agricultural inputs in the vegetables production system at the agricultural materials stage.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Agricultural  inputs | Unit | Global  warming  (kgCO2-eq unit−1) | Eutrophication  (kgPO4-eq unit−1) | Acidification  (kgSO2-eq unit−1) | Energy  equivalent (MJ unit−1) | References |
| N | kg | 8.3 | 0.00303 | 0.0252 | 50.5 | Zhang et al., 2013, Cui et al., 2013, Yue et al., 2013 |
| P2O5 | kg | 0.79 | 0.0000767 | 0.000602 | 5.00 | Zhang et al., 2013, Cui et al., 2013, Yue et al., 2013 |
| K2O | kg | 0.55 | 0.0000613 | 0.000482 | 14.7 | Zhang et al., 2013, Cui et al., 2013, Yue et al., 2013 |
| Manure Production | kg | / | / | / | 0.30 | Wang et al., 2018 |
| Pesticides | kg | 19.13 | 0.00194 | 0.0105 | 238 | Clark et al., 2016, Cui et al., 2013, Yue et al., 2013 |
| Plastic film | kg | 0.096 | 0.000103 | 0.00135 | 32.3 | He et al., 2016 |
| Diesel | L | 3.75 | 0.0119 | 0.0658 | 47.8 | Cui et al., 2013, Pishgar-Komlehet al., 2013 |
| Electricity | kWh | 0.75 | 0.00084 | 0.0145 | 12.5 | Yue et al., 2013 |

Supplementary Table 5. Pollutant emission factors during the farming stage in different types of vegetables production.

|  |  |  |
| --- | --- | --- |
| Loss pathway | Emission factors | References |
| Direct N2O emissions | 1.25% of N fertilizer input | Perrin et al., 2014, Wang et al., 2014 |
| Indirect N2O emissions | 1% NH3 emission +2.5% NO3 emission | Perrin et al., 2014, Wang et al., 2018 |
| NH3 emissions | 11.1% of N fertilizer input | Ti et al., 2015 |
| NO3 emissions | 9.97% of N fertilizer input | Zhao et al., 2010 |
| Phosphorus loss | 0.2% of total P2O5 fertilizer input | Chenet al., 2011, Wang et al., 2018 |

Supplementary Table 6. The market prices and yield benefits of different vegetables.

|  |  |  |
| --- | --- | --- |
| Vegetables | Price ($ Mg-1) | Yield benefits ($ ha-1) |
| Asparagus Lettuce | 217 | 19692 |
| Green Onion | 507 | 41652 |
| Radish | 174 | 13375 |
| Chinese Cabbage | 145 | 17729 |
| Green | 145 | 8907 |
| Spring Onion | 406 | 21989 |
| Cabbage | 159 | 16446 |
| Pepper | 870 | 21201 |
| Eggplant | 319 | 13157 |

Supplementary Table 7. Various unit prices used to calculate agricultural input costs for vegetable production.

|  |  |  |
| --- | --- | --- |
| Particulars | Unit | Price ($ unit-1)） |
| N | kg | 1.02 |
| P2O5 | kg | 3.99 |
| K2O | kg | 1.39 |
| Electricity | kWh | 0.08 |
| Diesel | l | 0.99 |
| Insecticide | kg | 135.48 |
| Fungicide | kg | 120.44 |
| Herbicide | kg | 245.74 |
| Labor | h | 2.17 |
| Plastic film | kg | 2.03 |
| Machinery | h | 26.10 |

Note: The unit prices of electricity, diesel, insecticide, fungicide, and herbicide were referred from Zhou et al. (2023 a), and N, P2O5, K2O, labor, plastic film, and machinery were determined based on the local market price (averaged from 2019-2022). Additionally, the survey showed that machinery was charged by the hour of vegetable production in the Erhai Basin, including purchasing, maintaining, and depreciating agricultural machinery.

Supplementary Table 8. The optimized management information of nine vegetable under different management practices (FP, S1, S2, and S3). FP is the current agricultural practices of farmers in the basin; S1 is the soil remediation management; S2 is the soil remediation and optimized target yield management; S3 is the integrated soil–crop system management and integrated knowledge and products strategy.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | Vegetable | Yield  (Mg ha-1) | Vegetables variety1 | Plant density  (103 plant ha-1) | Soil remediation management | Plant date | Fertilizer rate (kg ha-1) | | | | References |
|  |  |  | N | P2O5 | K2O | Total |
| FP | Asparagus Lettuce | 91 |  | 113 | No soil conditioner  Chicken manure | Jul. to May of the following year | 652 | 627 | 573 | 1852 |  |
| Green Onion | 82 |  | 1425 | Annual | 414 | 423 | 298 | 1135 |  |
| Radish | 77 |  | 225 | Mid Jul. to May of the following year | 440 | 505 | 476 | 1421 |  |
| Chinese Cabbage | 122 |  | 63 | Annual | 763 | 660 | 601 | 2024 |  |
| Green | 61 |  | 336 | Aug. to May of the following year | 294 | 232 | 281 | 807 |  |
| Spring Onion | 54 |  | 1006 | Annual | 428 | 349 | 360 | 1137 |  |
| Cabbage | 103 |  | 86 | Oct. to mid Jul. of the following year | 321 | 279 | 259 | 859 |  |
| Pepper | 24 |  | 65 | Late Mar. to mid Aug. | 207 | 159 | 241 | 607 |  |
| Eggplant | 41 |  | 52 | Late Mar. to mid Aug. | 422 | 260 | 443 | 1125 |  |
| S1 | Asparagus Lettuce | 91 |  | 113 | Lime nitrogen  (30 kg N ha−1)  compost fertilizer | Jul. to May of the following year | 383 | 418 | 319 | 1120 |  |
| Green Onion | 82 |  | 1425 | Annual | 258 | 295 | 163 | 716 |  |
| Radish | 77 |  | 225 | Mid Jul. to May of the following year | 295 | 403 | 341 | 1039 |  |
| Chinese Cabbage | 122 |  | 63 | Annual | 489 | 433 | 337 | 1259 |  |
| Green | 61 |  | 336 | Aug. to May of the following year | 269 | 221 | 222 | 712 |  |
| Spring Onion | 54 |  | 1006 | Annual | 372 | 221 | 297 | 890 |  |
| Cabbage | 103 |  | 86 | Oct. to mid Jul. of the following year | 321 | 221 | 259 | 801 |  |
| Pepper | 24 |  | 65 | Late Mar. to mid Aug. | 207 | 221 | 241 | 669 |  |
| Eggplant | 41 |  | 52 | Late Mar. to mid Aug. | 182 | 221 | 255 | 659 |  |
| S2 | Asparagus Lettuce | 129 |  | 120 | Lime nitrogen  (30 kg N ha−1)  compost fertilizer | Jul. to May of the following year | 383 | 418 | 319 | 1120 |  |
| Green Onion | 98 |  | 1350 | Annual | 258 | 295 | 163 | 716 |  |
| Radish | 113 |  | 225 | Mid Jul. to May of the following year | 295 | 403 | 341 | 1039 |  |
| Chinese Cabbage | 188 |  | 60 | Annual | 489 | 433 | 337 | 1259 |  |
| Green | 90 |  | 345 | Aug. to May of the following year | 269 | 221 | 222 | 712 |  |
| Spring Onion | 72 |  | 1100 | Annual | 372 | 221 | 297 | 890 |  |
| Cabbage | 116 |  | 90 | Oct. to mid Jul. of the following year | 321 | 221 | 259 | 801 |  |
| Pepper | 50 |  | 70 | Late Mar. to mid Aug. | 207 | 221 | 241 | 669 |  |
| Eggplant | 54 |  | 53 | Late Mar. to mid Aug. | 182 | 221 | 255 | 659 |  |
| S3 | Asparagus Lettuce | 129 | Hongjianye, Hongxiangfei | 120 | Lime nitrogen  (30 kg N ha−1)  compost fertilizer | Oct. to Jan. of the following year | 248 | 133 | 199 | 580 | Chen et al., 2023 |
| Green Onion | 98 | Sanyuexiu | 1350 | Sep. to Oct. | 170 | 60 | 60 | 290 | Zhang et al., 2009 |
| Radish | 113 | Baiyuchun | 225 | Mar. to Apr., Aug. to Sep. | 170 | 0 | 275 | 445 | Zhang et al., 2009 |
| Chinese Cabbage | 188 | Zhengzao 3, Lubai 8 | 60 | Aug. to late Oct. | 270 | 50 | 300 | 620 | Zhang et al., 2009 |
| Green | 90 | Lvgan | 345 | Late Aug. to early Nov. | 210 | 30 | 240 | 480 | Zhang et al., 2009 |
| Spring Onion | 72 | Tieganchun | 1100 | Dec. | 120 | 60 | 60 | 240 | Zhang et al., 2009 |
| Cabbage | 116 | Xiaotietou | 90 | Nov. to Jun. of the following year | 284 | 112 | 255 | 651 | Zhang et al., 2018 |
| Pepper | 50 | Honglv 5 | 70 | Apr. to May | 175 | 20 | 120 | 315 | Zhang et al., 2009 |
| Eggplant | 54 | Qieza 6 | 52.5 | Apr. to May | 187 | 82 | 130 | 399 | Ning et al., 2023 |

1 Farmers use a variety of cultivars for each type of vegetable, and the specific vegetable varieties in the Erhai Lake Basin under the FP, S1, and S2 strategies are not listed.

Supplementary Table 9. Comparison of input costs of agricultural production for different types of vegetables in subtropical plateau lake basin.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Vegetable types | Agricultural input costs ($ ha-1) | | | | | | | | | Total agricultural costs  ($ ha-1) |
|  | Fertilizers | plastic film | Electricity | Machinery | Diesel | Insecticide | Fungicide | Herbicide | Labor |  |
| Root Vegetables | 3836 | 150 | 27 | 1132 | 108 | 480 | 516 | 397 | 5713 | 12358 |
| Leafy Vegetables | 2845 | 98 | 26 | 1513 | 116 | 368 | 359 | 424 | 3455 | 9206 |
| Fruit Vegetables | 1432 | 159 | 15 | 1117 | 100 | 172 | 56 | 372 | 6691 | 10115 |

Supplementary Table 10. Comparison of environment damage costs for different types of vegetables in plateau lake basin.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Vegetable types | Environment damage costs ($ ha-1) | | | Total environmental cost ($ ha-1) |
|  | Global warming | Eutrophication | Acidification |  |
| Root Vegetables | 402 | 20 | 133 | 555 |
| Leafy Vegetables | 398 | 17 | 112 | 528 |
| Fruit Vegetables | 149 | 9 | 60 | 218 |

Supplementary Table 11. Nutrient input and uptake of different vegetable systems in the study area.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Vegetable | Yield  (Mg ha-1) | Fertilizers input  (kg ha-1) | | | | |  | Nutrients uptake  (kg ha-1) | | |  | Nutrients surplus  (kg ha-1) | | | References |
|  |  | N | P2O5 | | K2O | |  | N | P2O5 | K2O |  | N | P2O5 | K2O |  |
| Asparagus Lettuce | 91 | 652 | 627 | | 573 | |  | 212 | 67 | 327 |  | 440 | 560 | 246 | Hong, 2022 |
|  |  |  |  | |  | |  |  | 25 |  |  |  | 602 |  | Yan et al., 2013 |
| Green Onion | 82 | 414 | 423 | | 298 | |  | 117 | 22 | 79 |  | 297 | 401 | 219 | Zhang et al., 2009 |
|  |  |  |  | |  | |  | 157 | 23 | 139 |  | 257 | 400 | 159 | Li et al., 2022 |
|  |  |  |  | |  | |  |  | 24 |  |  |  | 399 |  | Yan et al., 2013 |
| Radish | 77 | 440 | 505 | | 476 | |  | 210 | 43 | 256 |  | 230 | 462 | 220 | Zhang et al., 2009 |
|  |  |  |  | |  | |  | 169 | 31 | 200 |  | 271 | 474 | 276 | Li et al., 2022 |
|  |  |  |  | |  | |  |  | 25 |  |  |  | 480 |  | Yan et al., 2013 |
| Chinese Cabbage | 122 | 763 | 660 | | 601 | |  | 288 | 42 | 155 |  | 475 | 618 | 446 | Zhang et al., 2009 |
|  |  |  |  | |  | |  | 48-258 | 3.2-46 |  |  | 505-715 | 614-657 |  | Zhou et a., 2023 b |
|  |  |  |  | |  | |  | 239 | 50 | 292 |  | 524 | 610 | 309 | Li et al., 2022 |
|  |  |  | |  | |  |  |  | 20 |  |  |  | 640 |  | Yan et al., 2013 |
|  |  |  | |  | |  |  | 253 | 118 | 355 |  | 510 | 542 | 246 | Huang 2017 |
| Green | 61 | 294 | | 232 | | 281 |  | 127 | 26 | 111 |  | 167 | 206 | 170 | Zhang et al., 2019 |
|  |  |  | |  | |  |  |  | 20 |  |  |  | 212 |  | Yan et al., 2013 |
| Spring Onion | 54 | 428 | | 349 | | 360 |  | 40-69 |  |  |  | 359-388 |  |  | Widiana et al., 2020 |
|  |  |  | |  | |  |  |  | 24 |  |  |  | 325 |  | Yan et al., 2013 |
| Cabbage | 103 | 321 | | 279 | | 259 |  | 200 | 80 | 200 |  | 121 | 199 | 59 | Boris et al., 2023 |
|  |  |  | |  | |  |  |  | 20 |  |  |  | 259 |  | Yan et al., 2013 |
|  |  |  | |  | |  |  | 310 | 80 | 274 |  | 11 | 199 | -15 | Huang 2017 |
| Pepper | 24 | 207 | | 159 | | 241 |  | 125 | 11 | 130 |  | 82 | 148 | 111 | Zhang et al., 2009 |
|  |  |  | |  | |  |  | 139 | 26 | 178 |  | 68 | 133 | 63 | Huang et al., 2007 |
|  |  |  | |  | |  |  |  | 48 |  |  |  | 111 |  | Yan et al., 2013 |
|  |  |  | |  | |  |  | 56 | 18 | 86 |  | 151 | 141 | 155 | Huang 2017 |
| Eggplant | 41 | 422 | | 260 | | 443 |  | 147 | 72 | 262 |  | 275 | 188 | 181 | Hong, 2022 |
|  |  |  | |  | |  |  | 127 | 29 | 201 |  | 295 | 231 | 242 | Huang et al., 2017 |
|  |  |  | |  | |  |  |  | 48 |  |  |  | 212 |  | Yan et al., 2013 |

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