

Response to Reviewer 3 Comments

Thank you for the time and effort spent in reviewing the manuscript. We acknowledge your comments and suggestions very much, which are valuable in improving the quality of our manuscript. Here are my responses to your questions and suggestions:

Point 1: General:

- (1) These terms should be explained better in the paper with provision of relevant references and be careful on their numbering. I would like to see also some more particular and specific data regarding temperatures, precipitations, soil texture and other.

Response: Thanks for the reviewer's kind suggestion. According to the experts' detailed suggestions below, we have explained the terms and cited references to supplement the description. For example, IDW (Line 190-195, Reference [30]), hierarchical cluster method and Delphi method (Line 205-209, Reference [31]), AHP (Line 296-297, Reference [34]), fuzzy statistical method (Line 299-301, Reference [2]), P-S-R (Line 308-310, Reference [36]), PCA (Line 377-380, Reference [31]). In addition, relevant temperature, precipitations, soil texture, and others are also supplemented in the part of the study area (Line 122 - 157).

- (2) I suggest to remove word "soil" from the title.

Response: Thanks for the reviewer's kind suggestion. I have modified the title to "Identification of Cultivated Land Quality Grade Using Fused Multi-source Data and Multi-temporal Crop Remote Sensing Information" (Line 2-4).

- (3) Figures 2, 3, 5, 6 and 7 are difficult in interpretation at the zoom of 53%, which corresponds to A4 paper – I suggest to increase the whole figures at least 1,5 times, and the font 2-3 times.

Response: Thanks for the reviewer's kind suggestion. According to these suggestions, I have adjusted the size and font size of the corresponding figures (Line 280, Line 425, Line 493, Line 516, Line 535).

Point 2: Detailed comments:

Line 50: In my opinion, outside of overall land/soil quality, the authors should also check the possibility of quick identification of main limiting factors (e.g. water excess or deficiency, soil erosion etc) for crop production.

Response: Thanks for the reviewer's kind suggestion. I agree with your comments, which have been supplemented there (Line 58-59).

Point 3: Materials and Methods:

- (1) Line 99-102: Please, add more information regarding Shandong Province with respective references:

- area;
- altitude (minimum, maximum, average and median values);
- slope (minimum, maximum, average and median values);
- temperature and precipitation (minimum, maximum, average and median values, data from many years);
- designation of climate according to Koppen-Geiger classification (<http://koeppen-geiger.vu-wien.ac.at/pdf/1901-1925.pdf> or other sources) or other, commonly used in the world;

- designation of WRB (2015) Soil Reference Groups (<https://www.isric.org/explore/wrb> – check the links at the bottom of this page and consult soil scientist) prevailing in the province;
- specify prevailing soil texture classes according to WRB or USDA (they are almost identical) Literature related to how remote sensing indices are useful for soil quality study is missing. Describe with examples from NDVI, SAVI, etc.

Response: Thanks for the reviewer's kind suggestion. According to this advice, I have supplemented the relevant information on Shandong Province and reference (Reference [27], [28]). Such as the study area (Line 121-124), altitude (Line 132), slope (Line 130-132), temperature and precipitation (Line 126-129). At the same time, the information on climate (Line 124-125), soil type (Line 132-139), and soil texture (Line 139-142) shall be revised to international standards according to the suggestions of experts.

- (2) Line 109: Please, specify, if “deep soil layer” refer sto it's upper, usually dark and rather rich in humus, layer (A), which is most commonly known as “topsoil” or “accumulation layer”. The term “soil” refers not only to this upper layer, but includes also deeper layers (most frequently: eluviation and illuviation) which has been formed due to pedogenic processes.

Response: Thanks for the reviewer's kind suggestion. The author's original intention of the sentence “with a deep soil layer” is to express that the plough layer of the cultivated land in the study area is relatively deep, rather than the characteristics of deep soil, which belongs to improper translation. It has been modified according to expert advice (Line 141-142).

- (3) Lines 114-115: Please, provide examples of crops, which are most frequently cultivated in two-crops season.

Response: Thanks for the reviewer's kind suggestion. The double-season crop is mainly wheat and corn, and the common one-season crop is cotton and peanut in the study area. I have added in the article (Line 147-150).

- (4) Lines 117-119: Please, recalculate and provide the power of machinery and amount of fertilizers used on hectare basis (i.e kW/ha and kgNPK/ha).

Response: Thanks for the reviewer's kind suggestion. After recalculation, the power of agricultural machinery is 19.542 kW/ha, and the amount of chemical fertilizer is 847.621 kg/ha. It has been modified according to expert advice (Line 150-155).

- (5) Before line 127: Please, create here new subchapter: "2.2. Soil sampling, analysis and data transformation" and ammend numeration of next subchapters.

Response: Thanks for the reviewer's kind suggestion. According to this advice, I have revised several titles and numbers of the article (Line 161, 162, 196, 223-224, 225, 247).

- (6) Line 131: The soil samples should be taken at least to the depth of about 90-100cm. The characterization of topsoil, at least in terms of soil texture is insufficient for the purposes of evaluation of land quality for majority of crops. This issue cannot be amended in this paper but consider it in future studies. Remember, that the soil with loamy sand layer in the top 30cm and underlaid by loam may be of better quality and productivity, than soil loam layer (0-30cm) underlaid by loamy sand.

Response: Thanks for the reviewer's kind suggestion. I quite agree with this point. The problems pointed out by experts are of great significance to our academic research, and we will focus on them and make corrections in future research.

- (7) Lines 133-134: Please, provide information of the number of samples taken (at least sum from the line 285).

Response: Thanks for the reviewer's kind suggestion. A total of 9673 sampling points have been arranged in this study, which has been supplemented in this paper (Line 168-170).

- (8) Line 135: Please, add paragraph or a table on the definition and characterization of soil physical properties, which are mentioned in the Table 1 and respective references. It is hard to suppose, what is the exact definition and units (or other scale) for Irrigation and drainage capacity, Topography (slope, topographic wetness index or something else?), Cultivated layer texture (according to USDA or WRB - soil texture class or soil texture grouping, or rather according to Chinese classification, which, in such case, should be shortly described in supplementary file, if needed), texture configuration (?), Salinization (EC or rather salt content, how it was measured?). Some of these indicators is mentioned in lines 143-145, but they should be defined precisely. I suggest to prepare a table with these characters and at least four columns: name (e.g. effective soil thickness), short definition, units, and source of definition.

Response: Thanks for the reviewer's kind suggestion. After proofreading, it is found that the name translation of some indicators in the original manuscript is not standard, which brings reading difficulties to experts and readers, and has been revised. For example, change "Topography" to "Parts of the terrain", change "Cultivated layer texture" to "Plough layer texture", and change "Texture configuration" to "Soil texture profile". The part of cultivated land quality evaluation based on GIS mainly refers to China's "cultivated land quality grade (GB/T 33469-2016)" (<https://www.chinesestandard.net/PDF/BOOK.aspx/GBT33469-2016>). In order to facilitate reading, according to experts' opinions, we added the description of cultivated land quality indicators in Supplementary Materials 1 (Table 1. Description of soil quality indicators.) and introduced the basic definition, unit, source, and references of soil physical indicators.

- (9) Lines 136-141: Please add more detailed information regarding soil analysis methods (e.g. concentration of ammonium acetate for determination of potassium and extractant used before pH determination – was it distilled water, or 1N KCl, or other?) and respective references. Please add information and definitions and references for "Biodiversity" and "Farmland shelterbelt", which are mentioned in Table 1.

Response: Thanks for the reviewer's kind suggestion. We describe the test and analysis of soil chemical indicators in the Supplementary Materials. See Supplementary Materials 1 (Table 1. Description of soil quality indicators.) for details. The configuration of ammonium acetate solution for determining rapidly available potassium is $c(\text{CH}_3\text{COONH}_4) = 1.0 \text{ mol} \cdot \text{L}^{-1}$. KCl solution is used as the extractant before pH determination. See "Cultivated land quality grade (GB/T 33469-2016)" for a detailed operation process (<https://www.chinesestandard.net/PDF/BOOK.aspx/GBT33469-2016>) (Reference [29]). At the same time, we have added the basic information and references of biodiversity and farmland shelterbelt in Supplementary Materials 1 (Table 1. Description of soil quality indicators.) with reference to China's "cultivated land quality grade (GB/T 33469-2016)" (<https://www.chinesestandard.net/PDF/BOOK.aspx/GBT33469-2016>).

- (10) Line 146: Please, provide slightly more detailed information on IDW interpolation method, relevant reference and information, why this method was selected.

Response: Thanks for the reviewer's kind suggestion. IDW interpolation takes the distance between interpolation points and sample points as the weight for the weighted average. It has the advantages of simple principle, fast calculation speed, intuition, and efficiency. I have

described the concept and advantages of IDW interpolation in this paper and cited references (Line 190-195, Reference [30]).

(11) After line 148 an information regarding methodology of weights determination, which are provided in Table 1.

Response: Thanks for the reviewer's kind suggestion. By referring to experts' suggestions, in order to better reflect the hierarchy of evaluation, we decided to put the description of the analytic hierarchy process method (Method of determining weight) in the part of "2.4.2 cultivated land quality evaluation based on GIS" (Line 296-297). At the same time, the Delphi method and hierarchical cluster method related to indicator selection are supplemented for a brief description in the part of "2.2. Soil Sampling, Analysis, and Data Transformation" (Line 205-209).

(12) Line 149: I think, this is a title of subchapter and should be 2.2 which should be changed in 2.3, if my suggestions are accepted.

Response: Thanks for the reviewer's kind suggestion. We have accepted the opinions of experts and revised the number of the title (Line 223-224).

(13) Lines 161 and others: Please add information of the producer (provider) and version of software used.

Response: Thanks for the reviewer's kind suggestion. The producer and version information of MRT tools (Line 239-242), ArcGIS software (Line 242-243), ENVI software (Line 243-245), and ENMAP-BOX software (Line 289-290) have been supplemented.

(14) Line 206: Please, explain the P-S-R framework (pressure- state- response?).

Response: Thanks for the reviewer's kind suggestion. Pressure - State - Response (P-S-R) was initiated by the Organization for Economic co-operation and Development to carry out the ecological environment assessment, which laid the foundation for ecological environment management and health assessments research. We have explained the P-S-R framework in this paper (Line 308-310, Reference [36]).

(15) Line 209: In my opinion, the term "limiting factor" would be more appropriate than "obstacle factor".

Response: Thanks for the reviewer's kind suggestion. We agree with the expert opinion and have revised the "obstacle factor" to the "limiting factor" in the paper (Line 317).

(16) Lines 217, 218, 219: please add the meaning for NDVI (Normalized Difference Vegetation Index?), DVI and RVI and sources, if others than [30] were used.

Response: Thanks for the reviewer's kind suggestion. According to this advice, we have given the full names and references of NDVI (Line 326-327, Reference [37]), DVI (Line 328-329, Reference [37]), and RVI (Line 330, Reference [37]) indicators, and added a table (Table 1, Line 333) to describe the band information required for the indicator calculation in detail.

(17) Lines 230-232: Please explain the indicators mentioned – ALI, AMI, AII and AFI. How are they calculated (or determined) and provide reference. Information on values of these indicators should be also provided, at least as supplementary file.

Response: Thanks for the reviewer's kind suggestion. According to this advice, we have supplemented a table (Table 2) and cited references (Reference [28]) to explain the expression of these four indicators (Line 350).

(18) KMO and Bartlett test (line 364) were not mentioned in Materials and Methods, please, add some information and reference!

Response: Thanks for the reviewer's kind suggestion. KMO and Bartlett spherical tests are used to check the information overlap of variables, which have been supplemented in the part of "2.4.4 Extraction of Soil Status Indicators under Three Situations" (Line 384-387), and added references (Reference [39]).

Point 3: Results and analysis:

(1) The values of all indicators, obtained or calculated in the study and their descriptive statistics (minimum, maximum, median and mean values) should be provided in results or in supplementary file. I suggest to add some of them in Materials in Methods, as they contribute to characterization of area of study (altitude, slope, temperature, precipitations), however the interpretation of results of the study require knowledge of values of these indicators (soil quality indicators mentioned in Table 1, slope, precipitations, temperature, NDVI, DVI and RVI, ALI, AMI, AII and other mentioned in Table 2 and in the text)!

Response: Thanks for the reviewer's kind suggestion. According to expert's opinions, we have made a supplementary description of the altitude, slope, temperature, and precipitation in the study area (Line 121-132). At the same time, we added Supplementary Materials 2 (Table 1. Descriptive statistical and analysis table of soil quality evaluation indicators.) to analyze the descriptive statistical characteristics of soil quality indicators. And we added Supplementary Materials 2 (Table 2. Descriptive statistical table of soil quality characteristic indicators.) to analyze the descriptive statistical characteristics of soil quality characteristic indicators and make the corresponding supplement in the paper (Line 431-438, Line 477-480, Line 483-485).

(2) Line 344-346: Here, the authors should cite particular information regarding slope, precipitation and temperature values, proving favourable natural conditions for crop growth.

Response: Thanks for the reviewer's kind suggestion. According to expert's opinions, the descriptive statistical value of each indicator roughly reflects the relevant information of the study area (Line 477-480, Line 483-485), and references (Reference [40] and [41]) are added to illustrate the contribution of indicators to crop growth and soil quality (Line 480-482, Line 485-487).

(3) Figure 5: Besides increasing of the dimension of the figure and font, please, fit this figure and its caption and not to a single page.

Response: Thanks for the reviewer's kind suggestion. According to expert's opinions, we have increased the image size, text size, and resolution of Figure 5, and adjusted the image and title to the same page (Line 493-495).

(4) Table 3:

- please, fit the whole table 3 and the notes to a single page.

- please add information on meaning of all soil state indicators - x1-x8 - from formulas. Which indicator is designed as x1, x2 etc?

Response: Thanks for the reviewer's kind suggestion. According to expert's opinions, we split the table into two parts, retain the results of the principal component analysis in Table 4 (Line 511), and the specific principal component expression is shown in Supplementary Materials 3 (Table 1. Principal component analysis results of soil state indicators.). After modification, tables and notes are on the same page. x1-x8 are the remote sensing indicators corresponding to the time phase, which have been further clarified in the tables and notes in Supplementary Materials 3.

Point 4: Conclusions:

Lines 489-492: The conclusion (2) fits better to materials and methods (line 206) than to conclusions - it seems to be the supposition made at the beginning of the study.

Response: Thanks for the reviewer's kind suggestion. I agree with your comments. So we take the conclusion (2) as the material and method, and the relevant contents are deleted from the Abstract (Line 28-31) and Conclusion (Line 645-648).