Study of Agro-soil & water System State of High Quality Apple Planting District in Dry Northern Weihe Loess Plateau

Yan Baowen1*, Li Xianwen1 and Song Songbai1

1 College of water conservancy and architecture engineering, Northwest A&F University, YangLing, Shaanxi, 712100, China

*Corresponding author’s e-mail: yanbaowen2000@163.com

Abstract: The dry North Weihe Loess Plateau is the most splendid climatic district for apple to grow in China. Take Baishui county as an instance, beginning with the structure of Agro-soil & water system for apple growing, this paper analyses the relationships between the elements of Agro-soil & water and the factors of apple quality in this representative small district, thus selecting the elements which are suitable to assess the Agro-soil & water system state. After setting up the assessment system of Agro-soil & water system via AHP method, the Agro-soil & water system state in Baishui country is assessed, through which the preponderance Agro-soil & water environment growing-belt plan in present conditions is acquired. Then the paper offers some advice on apple growing and Agro-soil & water system studying. Additionally, the study tries to put forward a new method to subdivide the preponderance apple growing belts and accelerate the apple production with a higher quality.

1. Introduction

Research on the water and soil environment begins at the 4th century B.C., while ancient Greece study endemic disease, from then on, people realized gradually the environment (geological or water and soil) affects the human health greatly [1]. At the end of 19th century, in a book, *Principle of Human &Earth*, Brash [France] proposed that relation between human and the geological environment is the preliminary relation of mankind, symbolized the people have already noted the bidirectional relationship between human and the water and soil environment [2-3]. Conception of the agricultural water and soil environment is determined in China earlier than 1990's, but now its research still be hidden in other agricultural principles, such as Geology, Soil science, Irrigation and water conservation, Water quality and Water environment and so on [4-6], there still has no systematic character on its content. Although progress has been made in many important aspects of the agricultural water and soil environment system, there still has less achievement in research on influence that element of water and soil system to the agricultural production. In fact, lots of researches of agricultural geology may integrate into agricultural soil and water environmental. For instance, geologists of former Soviet Union ever made fertilizer by the glauconitic, enhanced the crops output greatly, Japanese scientists has done many study on the relation between soil’s trace element and the zoology and botany [7]. Then cooperate with the agriculture department of state, Chinese geologist made great progress in the field of agriculture geology background investigation, as well as in relationship between some crops like tea, the flue-cured tobacco, the sweet orange, and the agricultural geology background [8-10]. And, National Department of Natural Resources of China ever organized the work of agricultural environment geological investigation, which involved in 17 provinces and took the soil geochemistry characteristic as the primary coverage.
But until now, the key research of agricultural soil and water environmental still focus on the soil’s born, its form, and the evolution affect agriculture, and also focus on the function and the variation characteristic of the agricultural water environment, and the movement rule of soil moisture in the farmland. While the research on the background factors of soil like bedrock, its geology background, physics and chemistry characteristic of the agriculture water resources, which also influence crops’ growing process and the quality and yields, even the agricultural production, yet not be enough emphasized. Chinese scientists achieved limited progress on this aspect, but special research of soil and water environmental condition to the apple planting not yet to be found now.

At present, Shaanxi is the sown area of apple growing and the ultimate output province throughout the country. In 2016, the output of fresh apple in Shaanxi is over 11,000,000 tons, accounts for 25% of the national apple output, and 7% of the world’s output. The north Weihe dry plateau area is situated at middle Shaanxi Province, and it includes south part of North Shaanxi plateau and the north Guanzhong terrace plateau, total area approximately is 42,900 km²[11]. This area is one of the most superior climatic region of state’s high quality apple planting, time of the apple planting here is more than 400 years, but some problems increasingly appeared in recent years, such as, expansion of apple-planting area without planning, and the slow promoted speed of high quality apples’ planting, and so on. In fact, all of these can be owing to the thinking shortage of the influence of soil and water elements to quality of apples, and dividing the planting belt only according to the climatic factors. And, this kind of influence has been already verified in those old apple plant areas, such as Shandong and Liaoning province, China. Many specialists already pointed out that, production of high quality apple needs not only suitable climatic conditions and scientific management, but also the corresponding landform, the moisture content, the soil structure, geochemistry background and other water and soil environmental condition[12]. Therefore, the best high quality apple’s planting condition should be the compound of climatic and water and soil conditions.

2. Test District

2.1. Climate belt on apple planting

Baishui county lies in the typical apple climate district area (figure 1) of China, it is located at a place of latitude 35°N and longitude 109°E, belongs to Weinan city, Shaanxi province. Who includes 15 towns, and has population of approximately 220,000. The county lies in semi-arid area of northwest China, average annual temperature is 10~13°C. Temperature increases progressively from northwest to southwest. Total annual rainfall is 550~650mm, increases from east to west. Its precipitation
concentrates in two seasons, summer and fall, accounts for 80% of the whole year, mostly occur in July. Baishui county has 2600–2800 sunshine hours per year [13-14]. All these conditions exactly content with the requirement under which the high quality apple can grow [15-16]. According to the climatic conditions, Baishui county can be divided into superiority climate area, which includes northern Luohe river and northeast part of county; the medium superiority area, which includes northwest part and the centre part of county; and, the weak superiority area, which lies in the southeast area of county. Figure 1 show us this divided result.

2.2. Condition of Agricultural Soil and Water
Total area of Baishui county is 97,800 ha, in which farming area is about 61,000 ha, among it the apple planting area reaches 27,200 ha, accounts for nearly half of the farming area. The total apple output reaches 595,000 tons in 2017. In the county the apple planting history lasted for more than 400 years. At present, Red Fuji and Marshal are two mainly planted kinds here. Whether the soluble solid, the sugar content, or the shape and the color, apples produced here shows its higher, even superior quality.

2.2.1. Topography. Baishui county is higher in northwest, lower in southeast. It is a typical landform of loess remnant plateau, and contains 4 kinds of specific typical landform, namely, loess lower mountain, loess long hills and round hills, residue loess plateau and loess river valley.

2.2.2. Strata. Within the county, quaternary loess cover most part of it, the master stratum is the Q2 Lishi group and Q3 Malan group, in the northern county, belt-shaped quaternary alluvium deposition distribute on both sides of Luohe river valley. Most soil of Baishui county have a parent material of loess, include the cinnamon soils, the cultivated loessial soils, the loess, and the humid-thermo ferrallitic, among them, loess and the cultivated loessial soils cover 85% of the total area, and the cinnamon soils and the cultivated loessial soils (account for 21%) is the apple eugenics advantageous soils. As a whole, characteristic of soil fertility is rich in potassium, lack in phosphorus, and medium in nitrogen. In addition, it is imbalance between nitrogen and phosphorus. As to the trace element, the copper may qualify with the apple’s growing, but the iron is inadequate.

2.2.3. Hydrogeology. In the county, types of grounder water only include the overburden layer hole crevice water, the bedrock crevice water and the limestone crevice water. Burying depth of ground water surface is over 100m, so it is difficult to use in agriculture. Therefore Baishui county's underground water source is deep-buried confined water. Besides the underground water, Lingao reservoir and Tieniu river reservoir may partly provide the irrigation water used for the apple orchard.

3. Material and Method

3.1. Sampling and test
Seven group samples are taken, four from the orchards which lies in the medium climatic belt and three from the superior climatic region, among Baishui county’s fourteen villages and towns, sampling point are all selected in the mature garden, use GPS to determine the sampling position, each place chooses two gardens. 30 Fuji apple samples are gotten in each garden, and from the tree must grow over 8 years. 3 quality indexes (firmness, dissolved solid, shape index) are tested in the field. Other ten chemistry quality indexes, include total sugar, total acid, Vc content, water content, Ca, Fe, Mn, Zn, Cu and Mg are gotten from lab testing. Soil samples are gotten by using the 4cm diameter half-moon shovel, depth of each hole is 3.0m, samples are taken in 0.5m, 1.5m and 3.0m separately, and two samples are taken in each depth, and then mixed them as one. Two holes are dogged in each garden, distance over 100m is required between two holes, thus guarantee the representation of the test result. Using atomic absorption spectrographic methods, concentration of Cu, Fe, Ma, Zn, Ca and Mg of soil sample are determined, at the same time, alkaline nitrogen, quick potassium, quick phosphorus and
organic content have be gotten by chemical process. Both surface water and ground water have been sampled, unless there is no surface water can be used as irrigation water. Volume of each water sample must be over 2.5L, and its pH value, the concentration of Ca, Mg, Cu, Fe, Mn, Zn and the total ion value are tested, same as the soil sample.

3.2. Analysis method
Using the average value of every index of sample as the general value, thus obtain the apple quality factor of 7 villages and towns. Correlation analytic method has been used to analysis the relation between the essential apple quality factor and soil condition factor, water condition factors. Analytic Hierarchy Process (AHP) has been applied to determine the essential soil and water environment factors’ weigh value on the apple quality [17-19]. At last, Surfer software has been used to draw the functional map of isoclines.

4. Result Analyses
Based on the averaging method, content value of respective factors in different plots can be obtained, result show on table 1:

| sampling plot | Dayang | Mengong | Shiguan | Shoushui | Beijingout | Yaohe | leiya |
|---------------|--------|---------|---------|----------|------------|-------|-------|
| Ca ug/ml      | 40.70  | 28.72   | 46.75   | none     | 44.25      | none  | 9.45  |
| Mg ug/ml      | 0.69   | 0.59    | 0.33    | none     | 0.60       | 0.66  |
| Cu ug/ml      | 0.07   | 0.07    | 0.10    | none     | 0.06       | 0.10  |
| Fe ug/ml      | 0.26   | 0.06    | 0.03    | 0.14     | none       | 0.34  |
| Mn ug/ml      | 0.16   | 0.08    | 0.08    | 0.10     | none       | 0.06  |
| Zn ug/ml      | undetect | undetect | undetect | undetect | undetect | undetect | undetect |
| Total salt mg/l | 476.00 | 391.00  | 1276.00 | none     | 507.00     | none  | 501.00 |
| PH            | 6.00   | 6.50    | 6.30    | none     | 6.00       | 6.00  |
| Ca ug/ml      | 42.00  | 42.85   | none    | 45.58    | none       | 42.48 |
| Mg ug/ml      | 0.74   | 0.47    | none    | 0.54     | none       | 0.54  |
| Cu ug/ml      | 0.11   | 0.08    | none    | 0.08     | none       | 0.12  |
| Fe ug/ml      | 0.69   | 0.05    | none    | 0.28     | none       | 0.09  |
| Mn ug/ml      | 0.12   | 0.12    | none    | 0.08     | none       | 0.05  |
| Zn ug/ml      | 0.58   | undetect| undetect| undetect | none       | 0.06  |
| Total Salt mg/l | 488.00 | 661.00  | none    | 558.00   | none       | 538.00 |
| PH            | 6.50   | 6.00    | 6.00    | 6.00     | 6.00       | 6.50  |
| Alk-N mg/kg   | 32.00  | 28.00   | 26.50   | 18.00    | 62.00      | 19.50 |
| Quick P mg/kg | 2.55   | 2.65    | 7.15    | 1.95     | 80.65      | 6.85  |
| Quick K mg/kg | 97.00  | 106.50  | 95.00   | 73.50    | 207.00     | 71.50 |
| Organic g/mg  | 8.75   | 10.05   | 6.40    | 5.95     | 12.35      | 7.45  |
| PH            | 8.14   | 8.26    | 8.84    | 8.36     | 8.13       | 8.31  |
| Cu ug/g       | 22.00  | 19.25   | 13.50   | 17.88    | 19.00      | 19.25 |
| Fe ug/g       | 2.88   | 2.40    | 1.59    | 2.24     | 2.45       | 2.04  |
| Mn ug/g       | 575.00 | 590.00  | 460.00  | 581.50   | 544.00     | 526.50 |
| Zn ug/g       | 82.50  | 82.50   | 75.00   | 92.50    | 80.50      | 76.50 |
| Ca %          | 2.99   | 4.44    | 5.27    | 4.95     | 5.64       | 6.75  |
| Mg %          | 0.95   | 0.97    | 0.65    | 1.01     | 0.93       | 0.97  |
| Ca %          | 2.99   | 4.44    | 5.27    | 4.95     | 5.64       | 6.75  |
| Mg %          | 0.95   | 0.97    | 0.65    | 1.01     | 0.93       | 0.97  |
Table 2. Relative value of respective factors in different plots

| Item          | Total Sug | Total acid | Vc mg/100g | Moisture % | Micro-element | Firmness | Dissolved solid | Shape index |
|---------------|-----------|------------|------------|------------|---------------|----------|-----------------|-------------|
| Ca            | -0.816    | 0.027      | -0.471     | 0.734      | -0.439        | 0.823    | -0.627          |
| Mg            | 0.360     | -0.192     | -0.031     | -0.270     | 0.508         | -0.007   | 0.625           |
| Cu            | 0.614     | -0.300     | 0.044      | -0.219     | 0.003         | 0.784    | -0.118          |
| Fe            | 0.825     | -0.690     | -0.337     | -0.122     | -0.214        | 0.442    | 0.342           |
| Mn            | -0.357    | -0.308     | -0.593     | 0.382      | -0.110        | -0.762   | 0.064           |
| Total Salt    | -0.151    | -0.152     | -0.253     | 0.392      | 0.483         | -0.635   | 0.080           |
| PH            | -0.517    | 0.901      | 0.795      | -0.531     | -0.393        | -0.294   | -0.101          |
| Ca            | -0.363    | 0.593      | 0.210      | -0.119     | -0.519        | -0.373   | -0.348          |
| Mg            | 0.009     | -0.906     | -0.958     | 0.841      | 0.431         | -0.582   | -0.265          |
| Cu            | 0.266     | -0.839     | -0.335     | 0.045      | 0.635         | -0.214   | 0.576           |
| Fe            | -0.250    | -0.428     | -0.841     | 0.846      | -0.001        | -0.764   | -0.644          |
| Mn            | -0.839    | 0.307      | -0.166     | 0.416      | 0.004         | -0.645   | -0.906          |
| Zn            | -0.618    | -0.940     | -0.985     | 0.990      | 0.816         | -0.523   | -0.923          |
| Total Salt    | -0.294    | 0.690      | 0.755      | -0.537     | -0.012        | 0.486    | -0.033          |
| PH            | -0.030    | -0.910     | -0.832     | 0.760      | 0.639         | -0.387   | -0.217          |
| Alkali N      | -0.612    | -0.275     | -0.513     | 0.748      | 0.659         | 0.297    | -0.559          |
| Quick P       | -0.393    | -0.191     | -0.385     | 0.645      | 0.540         | 0.484    | -0.328          |
| Quick K       | -0.600    | -0.158     | -0.414     | 0.702      | 0.617         | 0.370    | -0.537          |
| Organic       | -0.711    | 0.055      | -0.141     | 0.397      | 0.484         | 0.285    | -0.525          |
| PH            | 0.021     | 0.003      | 0.014      | 0.069      | 0.098         | -0.537   | 0.177           |
| Cu            | 0.082     | -0.153     | -0.027     | -0.206     | -0.140        | 0.296    | -0.062          |
| Fe            | -0.095    | -0.186     | -0.268     | 0.092      | -0.056        | 0.255    | -0.415          |
| Mn            | 0.267     | 0.241      | 0.219      | -0.348     | -0.466        | 0.529    | -0.121          |
| Zn            | 0.584     | 0.218      | 0.046      | -0.181     | -0.661        | 0.527    | -0.084          |
| Ca            | 0.294     | 0.170      | 0.428      | -0.262     | 0.038         | 0.380    | 0.697           |
| Mg            | 0.488     | 0.214      | 0.326      | -0.489     | -0.531        | 0.686    | 0.207           |

In table 2 the negative value express inverse correlation relation, in order to reasonable simplify...
this, takes significance level $\alpha=0.10$ as standard, inquiry the examination value table, it shows, when 

$$|\gamma_{\text{surface water}}| > 0.8054; |\gamma_{\text{ground water}}| > 0.8054 \text{ (among which, } |\gamma_{\text{Zn}}| > 0.987) ; |\gamma_{\text{soil}}| > 0.6694$$

the relevance between two factors are good, corresponding values are shown in rough skew in table 2. AHP has been used to determine the important weight of soil and water factors to apples’ quality, then, by normalizing these weight values, following result can be obtained (table 3):

| Sampling plot      | Dayang mengong | Shiguan | Shoushui | Beijingout | Yaohe | leiya |
|--------------------|----------------|---------|----------|------------|-------|-------|
| **Ground water**   |                |         |          |            |       |       |
| Ca                 | -0.084         | -0.085  | -0.162   | -0.162     |       |       |
| Fe                 | 0.052          | 0.052   | 0.1      | 0.1        | 0.052 |       |
| PH                 | 0.042          | 0.042   | 0.081    | 0.081      | 0.042 |       |
| Mg                 | -0.045         | -0.045  | -0.055   | -0.055     | -0.045|       |
| Cu                 | -0.043         | -0.043  | -0.052   | -0.052     | -0.043|       |
| Fe                 | -0.006         | -0.006  | -0.007   | -0.007     | -0.006|       |
| Mn                 | -0.120         | -0.121  | -0.147   | -0.146     | -0.120|       |
| Zn                 | 0.005          |         |          |            |       |       |
| PH                 | -0.262         | -0.263  | -0.321   | 0.319      | -0.262|       |
| **Surface water**  |                |         |          |            |       |       |
| Alkali N           | 0.021          | 0.021   | 0.04     | 0.025      | 0.025 | 0.021 |
| quick-acting K     | 0.031          | 0.031   | 0.06     | 0.038      | 0.038 | 0.031 |
| **Soil**           |                |         |          |            |       |       |
| Ca                 | 0.083          | 0.084   | 0.16     | 0.102      | 0.101 | 0.083 |
| Mg                 | 0.147          | 0.148   | 0.283    | 0.180      | 0.283 | 0.179 |
| Organic material   | -0.059         | -0.059  | -0.114   | -0.073     | -0.072 | -0.059|
| Alkali N           | 0.003          | 0.003   | 0.005    | 0.002      | 0.002 | 0.002 |
| quick-acting K     | 0.004          | 0.005   | 0.008    | 0.004      | 0.001 | 0.000 |
| Ca                 | 0.007          | 0.011   | 0.024    | 0.014      | 0.026 | 0.020 |
| Mg                 | 0.022          | 0.022   | 0.028    | 0.028      | 0.041 | 0.027 |

Calculates the agricultural soil and water system mode’s judgment value with above data, result shown as follow (table 4):

| Sampling plot      | Dayang Mengong | Shiguan | Shoushui | Beijingout | Yaohe | leiya |
|--------------------|----------------|---------|----------|------------|-------|-------|
| **Ground water**   |                |         |          |            |       |       |
| Ca                 | -0.020         | -0.014  | -0.045   | -0.042     |       | -0.005 |
| Fe                 | 0.016          | 0.004   | 0.004    | 0.017      | 0.021 |       |
| PH                 | 0.008          | 0.009   | 0.017    | 0.016      | 0.008 |       |
| Mg                 | -0.011         | -0.007  | -0.010   | -0.010     | -0.010|       |
| Cu                 | -0.009         | -0.007  | -0.008   | -0.012     | -0.010|       |
| Fe                 | -0.004         | 0.000   | -0.002   | -0.001     | 0.000 |       |
| Mn                 | -0.035         | -0.035  | -0.029   | -0.018     | -0.012|       |
| Zn                 | 0.003          |         |          | 0.000      | 0.002 |       |
| PH                 | -0.055         | -0.051  | -0.062   | 0.062      | -0.055|       |
| **Surface water**  |                |         |          |            |       |       |
| Alkali N           | 0.003          | 0.003   | 0.005    | 0.002      | 0.002 | 0.002 |
| quick-acting K     | 0.004          | 0.005   | 0.008    | 0.004      | 0.004 | 0.003 |
| Organic material   | -0.009         | -0.010  | -0.013   | -0.008     | -0.025 | -0.009 | -0.006|
| Ca                 | 0.007          | 0.011   | 0.024    | 0.014      | 0.026 | 0.020 |
| Mg                 | 0.022          | 0.022   | 0.028    | 0.028      | 0.041 | 0.027 |
| **Soil**           |                |         |          |            |       |       |
| Alkali N           | 0.003          | 0.003   | 0.005    | 0.002      | 0.002 | 0.002 |
| quick-acting K     | 0.004          | 0.005   | 0.008    | 0.004      | 0.004 | 0.003 |
| Organic material   | -0.009         | -0.010  | -0.013   | -0.008     | -0.025 | -0.009 | -0.006|
| Ca                 | 0.007          | 0.011   | 0.024    | 0.014      | 0.026 | 0.020 |
| Mg                 | 0.022          | 0.022   | 0.028    | 0.028      | 0.041 | 0.027 |

According to the calculated results in table 4, draw the isoneph map of the judgment value of the regional agricultural soil and water system. Because the judgment value is too small, so expands them 100 times while drawing the map of figure 2.
4.1. Main influence factors of apple quality

Through correlation analysis and factors’ weight determination, we find some essential soil and water factors can influence the apple quality more greatly. In ground water, it is the content of Mn, and PH value. In soil, content of Mg is the most important influence factor to apple quality, the former is the negative correlation, so if ground water be used as irrigated water, its Mn content must arrive at a rather low concentration, and the alkalinity cannot be too high. Content of Mg shows a positive correlation relation with apples’ quality indexes, so high quality apple’s growing need a rather high Mg concentration in the soil. Above result also indicated that, to the high quality apple’s growing, most elements’ high concentration in the ground water is disadvantageous. But an opposite law shows in surface water, a coordination mechanism must be exist here [20-21], other paper will discuss that. In the study area, to some extent, using surface water as irrigated water source to irrigate apple is better than groundwater irrigation. In practice, there is also have a corresponding evidence. For example, town of Beijingtou list itself into one of the high quality apple planting district just because of surface water irrigation.

4.2. Superior belt determination

Based on the judgment value, we can classified the district that has a judgment value bigger than 0 as the superiority area of the high quality apple planting, while district that small than 0 as the non-superiority area, then three superiority areas of high quality apple planting in Baishui county can be got, one lies in northeast, include most Shiguan, part Zongmu and Leiya. Another lies in the western county, include Yaohe, Xudao and part Yuntai. Still another is south central of the county; include Beijingtou, city town and Chengjiao (figure 2). This division is different from that belt divided only according to the climatic condition. Obviously, this tells us that it is the combination of climatic conditions and the agricultural water and soil condition that determine the apple quality. Therefore, considering comprehensively, it can be seen that Shiguan, part Zongmu and Leiya in the northeast county, and Beijingtou, city town and Chengjiao in south central of the county are the superior areas for high quality apples’ planting.

Figure 2. Apple’s agro-soil &water belt in Baishui county
5. Summary
Through above analysis, targets for optimizing agriculture soil and water system environment about the Baishui county’s apple planting, conclusions and suggestions are given here:

- Based on both the soil and water conditions and the climate conditions, the high quality apple planting should be emphasized in two areas, around city town and Shiguan town, at the same time most western county is not suitable for enlarging the apple’s planting area although the climate is suitable in here.

- Use more surface water as irrigated water of apple orchid, with the suitable irrigation and water conservation facility to enlarge utilization degree of surface water, as far as possible less use the ground water, especially to those non-superiority area, thus transform the mode of agricultural soil and water system, causes it to turn towards favorite commercial production of the high quality apple.

- It is possible to enhance the agricultural soil and water system mode judgment value in non-superiority area through using surface water for apple tree’s irrigation and change the proportion of fertilizer application, special attention should be paid to the supplement of Ca and Mg element, and the appropriate amount of organic fertilizer should be used in order to avoid adverse consequences.

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