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Original Paper

Ranking of Placer Gold Prospects in Chile Through Analytic Hierarchy Process

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Chile has a rich, but poorly known history of placer gold mining. At present, this sector is almost nonexistent and there are some restrictions for its revival: disperse and partial information on existing resources and limited technical expertise to assess the potential of placer gold mine sites. This paper presents the background, methodology and results of the prioritization process of known prospects of this kind in Chile. This research was part of a publicly funded project aimed to incentivize the development of this industry. The ranking was carried out using the analytic hierarchy process, which allowed to include different quantitative and qualitative variables related to the economic potential, technical aspects, contextual viability and socioeconomic factors in the analysis. The results show that, despite the increasing relevance of environmental and community issues in mining development, the business potential and the economic/technical aspects are the main factors in the early selection of a site to advance in exploration and development activities. Both variables represented around 40% and 37% of weights in the final selection, respectively. In contrast, contextual viability and local socioeconomic impacts only accounted for the remaining 23%. This study also shows that the inclusion of experts with different backgrounds in the process enriches the analysis and does not significantly distort the final outcome of the prioritization. Finally, the relevance of using MCDM tools when assessing the attractiveness of mine sites for their development is highlighted, particularly when public funds for subsequent exploration activities are committed.

KEY WORDS: Placer gold, Exploration, Prioritization, AHP, Chile.

INTRODUCTION

Chile has achieved international recognition in the global mining industry for its copper mining industry, with close to 30% of worldwide production (Cochilco 2018). However, the country was not always known for these mining activities. From the time of the Spanish conquest to the beginning of the nineteenth century, a considerable part of Chilean mining activities was related to placer gold deposits (Vicuña 1932; Sutulov 1976; Cuadra and Dunkerley 1991; Portigliati 1999). Moreover, the end of the nineteenth and the beginning of the twentieth century ushered in a new age of renewed interest in exploiting the placer gold deposits in Chile (Sutulov 1976). However, placer gold mining has decreased considerably during the last century. Three essential factors led to this situation: (1) a constant ore grade reduction; (2) poor market conditions after the fall

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of the gold standard; and (3) environmental restrictions associated with the use of hydraulic mining and the application of mercury to amalgamate the gold (Cuadra and Dunkerley 1991). Nevertheless, more than 750 alluvial gold deposits and prospects have been identified in Chile (Latrille 1994; Portigliati 1999).

Currently, technological developments and a favorable market outlook for gold have facilitated extracting and processing lower ore grade while also minimizing environmental impacts, thus opening the space for a renaissance of the placer gold industry in Chile. Tough, its development is limited due to lack of or partial information on existing resources and restricted technical knowledge for assessing available mine sites to focus the efforts on exploration. To address these limitations, a group of researchers from the Departamento de Ingeniería de Minería (Department of Mining Engineering) at the Pontificia Universidad Católica de Chile (DIM-UC, Spanish acronym) submitted a project for government funding to develop a ranked survey of placer gold prospects in Chile. The final aim is to promote an exploration and exploitation industry of placer gold mining in the country.

To prioritize the placer gold sites/prospects in Chile, the analytic hierarchy process (AHP) was chosen due to its simplicity, feasibility of implementation and the ability to incorporate quantitative and qualitative variables such as subjective expert knowledge in the evaluation. The AHP methodology was developed by Saaty (1977, 1988, 1995), and it can be applied to multi-criteria decision-making (MCDM) problems. This process is highly useful for making group decisions including the selection of alternatives, prioritization of items or alternatives, resource allocation and the resolution of conflicts. Therefore, AHP is widely used in operations research and the business sciences. Furthermore, it has been used in the area of natural resources (Herath and Prato 2006; Mendoza and Martins 2006), and specifically in environmental and community-related assessments in mining (Blachowski 2015; Govindan 2015; Shen et al. 2015), mining exploitation issues (Suprakash and Uday 2012; Ataei et al. 2013; Sobczyk et al. 2017) and in mineral exploration and mineral potential/prospectivity mapping (Mohebi et al. 2014; Ahmadi et al. 2015; Du et al. 2016; Carranza 2017).

Although AHP has been used in mineral potential mapping for different mineral deposits (Pazand et al. 2011; Najafi et al. 2014; Asadi et al. 2016) and other methodologies have been applied to map prospectivity for gold deposits (Asadi and Hale 2001; Carranza and Hale 2003; Nykänen 2008; Costa e Silva et al. 2012; Carranza et al. 2015; Geranian et al. 2016), this is the first attempt (to the best of our knowledge) to use AHP to rank known placer gold prospects in a country.

This paper presents the background, methodology and results of the prioritization process for placer gold sites in Chile. The results of this study should be useful to: (a) efficient allocation of government funds for subsequent field-based activities to verify the information previously collected through an extensive bibliographic review, and (b) guiding future private efforts for more advanced explorations. This paper is structured as follows: The second section presents the data and methodology used for ranking the identified prospects; third section describes and discusses the results of the research; and the last section provides the study's main conclusions and some final recommendations.

METHODOLOGY AND DATA TO RANK PROSPECTS FOR GOLD PLACERS IN CHILE

Fundamentals of the AHP Method

The AHP divides complex multi-criteria decision problems into sets of subproblems, associated through a hierarchical structure. The problems are then solved via pairwise comparisons on the relative importance of each subproblem and respective criteria/alternatives. Three basic stages comprise AHP (Partovi and Hopton 1994; Pazand et al. 2011):

1. *Hierarchy design* In this first stage, the decision problem is divided into a set of subproblems by using a hierarchical structure. The first level of the structure is the final decision objective, whereas the final level identifies the available alternatives. The intermediate levels define the criteria, conditions or factors within the decision-making process (Saaty 2005; Jung 2011).
2. *Prioritization and logical consistency* In this second stage, the relative weights of each hierarchical level are evaluated through a pairwise comparison matrix constructed from expert's opinions. Then, simple mathematical operations are used to obtain weights

and priorities. These values are employed to calculate a score for each alternative within each subproblem of a hierarchal level. Finally, response robustness is measured by a consistency indicator (De Feo and De Gisi 2010).

Obtaining each matrix implies comparing pairs of criteria or alternatives in terms of relative importance as related to a proposition (Carranza 2008). The pairs are compared according to their levels of influence and based on specific criteria established by the immediately higher level (Najafi et al. 2014). The nominal scale usually applied allows experts to intuitively incorporate their experience and knowledge. Then, verbal preferences are translated into numeric evaluations. This numerical scale is, in practice, insensitive to small variations between expert preferences, thereby minimizing evaluation uncertainties (Partovi and Hopton 1994). The standardized scale between pairs is shown in Table 1 (Dagdeviren 2008; Najafi et al. 2014).

Consequently, comparison matrices are constructed as follows. If $C = \{C_j | j = 1, 2, \ldots, m\}$ is the available set of criteria, factors or alternatives for a subproblem of the MCDM, and a_{ij} is the relative expert preference (as established by a comparison scale) between the criteria i and j for $i, j = 1, \ldots m$, then the preference matrix of the expert can be expressed as (Joshi et al. 2011):

Table 1. Fundamental scale for pairwise comparisons in AHP (Saaty 2005)

Reciprocal (decimal)	Importance	Definition
1/9 (0.111)	9	Extremely important
1/8 (0.125)	8	Extremely to very important
1/7 (0.143)	7	Very important
1/6 (0.167)	6	Very important to important
1/5 (0.200)	5	Important
1/4 (0.250)	4	Important to moderately important
1/3 (0.333)	3	Moderately important
1/2 (0.500)	2	Moderately to equally important
1/1 (1.000)	1	Equally important

$$A = \begin{bmatrix} a_{11}a_{12} & \cdots & a_{1m} \\ a_{21}a_{22} & \cdots & a_{2m} \\ \vdots & \ddots & \vdots \\ a_{m1}a_{m2} & \cdots & a_{mm} \end{bmatrix}; \text{ in which}$$

$$a_{ii} = 1; a_{ji} = 1/a_{ij}; a_{ij}, a_{ji} \neq 0.$$

If the pairwise comparison matrix $A = (a_{ij})_{m \times m}$ satisfies the condition $a_{ij} = a_{ik}a_{kj}$ for any $i, j, k = 1, \ldots, m$, then A is a fully consistent matrix with a range equal to one. In this case, the relative weights of the criteria (weight vector $\boldsymbol{w}$) can be obtained by normalizing any row or column of matrix A (Dagdeviren 2008; Abedi et al. 2013). In contrast, if the matrix is inconsistent, then the weight vector $\boldsymbol{w}$ can be determined from the following relation:

$$A\boldsymbol{w} = \lambda_{\max}\boldsymbol{w}, \tag{2}$$

where $\lambda_{\max}$ is the maximum eigenvalue of the matrix A. This is called the principal right eigenvector (Saaty 1995; Pazand et al. 2011). The quality of AHP results is intrinsically related to the consistency of pairwise comparison and its associated matrix. This can be checked using the consistency ratio, which is calculated as:

$$\mathrm{CR} = \frac{(\lambda_{\max} - m)/(m-1)}{\mathrm{RI}}, \tag{3}$$

where RI is the random index, i.e., the average of the consistency indices resulting from matrix ordering, which corresponds to the degree of consistency that automatically arises in a random reciprocal matrix with values on a nine-level nominal scale (Macharis et al. 2004; Ying et al. 2007). If $\mathrm{CR} \leq 0.1$, then the process is consistent; if $0.1 \leq \mathrm{CR} \leq 0.5$, then the process is slightly inconsistent; otherwise, the results must be reviewed to make necessary adjustments or to repeat the process (Saaty 1995). This consistency measure serves to evaluate the results within a particular subproblem or the entire hierarchical structure. Furthermore, assessing consistency can detect errors in the process, erroneous judgments or even biases/exaggerations in expert answers (Partovi and Hopton 1994).

3. *Calculation of results* In the final stage of the AHP, the weights are calculated for the entire hierarchical structure of the MCDM problem. The alternative that obtains the highest eigenvector value within the entire

structure is considered the first choice (Saaty 1988; De Feo and De Gisi 2010). Two situations can exist for the final calculation. The first is that only one set of pairwise matrices is obtained through responses from one expert, or as agreed upon by all the experts participating in the AHP. In this case, results are obtained through the direct application of the AHP to the entire hierarchical structure. In the second situation, various sets of pairwise matrices exist, with one set per expert participating in the process. In this case, the results must be weighted using the vectors within the matrices of each expert ($\boldsymbol{w}_{x,y}$) by applying the geometric mean and according to the general weights assigned by each expert, $\propto_j$. Then, the following relationship is obtained.

If $\boldsymbol{w}_{x,y} = \begin{bmatrix} w_{1,x} \\ \vdots \\ w_{m,x} \end{bmatrix}$ is the weights vector of expert 'x' for the criteria or sub-criteria 'y' in Eq. 2, in which there are available alternatives in the subproblem, and if $W_y = [\, \boldsymbol{w}_{1,y} \quad \ldots \quad \boldsymbol{w}_{n,y} \,] = \begin{bmatrix} w_{1,1} & \ldots & w_{1,n} \\ \vdots & \ddots & \vdots \\ w_{m,1} & \ldots & w_{m,n} \end{bmatrix}$ is a matrix of $m \times n$ comprised by the weights vectors ($\boldsymbol{w}_{x,y}$) from each of the experts, then relative weight of each ith alternative for the criteria/sub-criteria can be determined through the weighted geometric mean of each row in the matrix $\mathbf{W_y}$ using the following equation:

$$w_i = \left(\prod_{j=1}^{n} w_{i,j}^{\propto_j} \right), \text{ subject to} \sum_{j=1}^{n} \propto_j = 1. \tag{4}$$

Hence, the final weight vectors $\bar{w}_y$ can be constructed by repeating this process for each one of the alternatives of the criteria or sub-criteria, with posterior normalization.
Therefore:

$$\bar{\boldsymbol{w}}_y = \begin{bmatrix} \bar{w}_1 \\ \vdots \\ \bar{w}_m \end{bmatrix}, \text{ in which } \bar{w}_j = w_j \bigg/ \sum_{i=1}^{m} w_i, \tag{5}$$

The weights vector $\bar{\boldsymbol{w}}_y$ obtained through the geometric mean (Eq. 5) is the equivalent for the case with multiple replies to the vector $\boldsymbol{w}$ obtained in Eq. 2 for the case with only one set of pairwise comparison.

Finally, once the multi-expert weights vector is obtained, calculations can proceed as in the case with only one participant in the AHP. The influence percentages are calculated against the global objective of each alternative (i.e., within the percentage range of the corresponding criteria in the immediately higher hierarchy level). Finally, the respective vector of each alternative is multiplied by the value of each criterion.

Application of AHP Methodology to Rank Placer Gold Prospects in Chile

Participants

Two teams participated in the process. The first team was comprised of participants based on their backgrounds and experiences in different aspects of mineral exploration, mining development and placer mining. The second team was comprised of participants from the overseeing entities of the project,[1] which were included because of their knowledge on diverse subjects considered relevant to the study: technical insights into the evaluation and development of small- to midsized mining projects and on local community relationships, and regulatory matters, contextual issues and mineral commodity markets.

Information on Placer Gold Sites/Prospects in Chile

The data compiled from an extensive bibliographic review and complemented with other databases and criteria fields related to the geographic locations of the mine sites. Unavailable information was estimated based on three factors: (a) prior field experience on the area; (b) similarities with nearby prospects; and (c) expert judgment of the principal researcher. The bibliographic review included all references associated with placer gold deposits and mine sites in Chile. This review was based on records at the leading geological and mining libraries in the

[1] One of the requirements for Corfo's Public Goods for Competitiveness Program is the inclusion of at least one overseeing public organism, which acts as a collaborator and partner to ensure public interest of the project results.

country. More than 730 documents, reports, scientific articles, publications and books were reviewed. More than 2100 references were recorded.[2] Based on this work, reports were drawn up for each relevant site, containing as minimum the following three criteria: (1) precise location of the area of interest; (2) data on ore grades; and (3) potential mineralization volume. The following data were also of interest (Wells 1989): area access points; type of deposit (sedimentation environment and deposit morphology); shape and extension of the mineralization; sediment column description; gold characteristics (size and morphology); and other relevant variables (e.g., water availability for exploitation; status of the mining property; superposition with protected or indigenous areas; and other available information). From the bibliographic review, 238 records were created, some of them matching the same deposits. Duplicate records were consolidated, resulting in 67 final reports. The process concluded by incorporating unique estimates on potential ore grades and volumes for each prospect. As a result, the prioritization comprised quantitative and qualitative factors.

On the other hand, the following quantitative variables were taken into consideration: potential resources[3] (PR), measured in contained ounces of gold (oz Au); ore grade (OG), measured in grams of gold per cubic meter (g/m^3); stripping ratio (SR), measured as the overburden thickness over the ore width ratio; and the differential rate of unemployment (DUR), within each respective area as compared to the national unemployment rate (%). The first three variables are directly related to the business potential and the last one to the socioeconomic impact that any productive initiative could have at the local level. Table 2 shows the ranges used to evaluate the quantitative variables during pairwise comparisons (equal for all the experts). The ranges were defined through a bibliographic review of placer projects around the world and using the experience of the research team.

On the other hand, the qualitative variables were divided into two groups. The ones in the first

Table 2. Ranges to assess quantitative variables in the prioritization model for placer gold prospects in Chile

Variables/ranges	Extremely important (9)	Very important (7)	Important (5)	Moderately important (3)	Equally important (1)
Potential resources	PR > 50 k oz Au (H-PR)	PR = 20–50 k oz Au (HI-PR)	PR = 10–20 k oz Au (I-PR)	PR = 3–10 k oz Au (LI-PR)	PR < 3 k oz Au (L-PR)
Ore grade	OG > 3.0 g/m^3 (H-OG)	OG = 1.5–3.0 g/m^3 (HI-OG)	OG = 1.0–1.5 g/m^3 (I-OG)	OG = 0.5–1.0 g/m^3 (LI-OG)	OG < 0.5 g/m^3 (L-OG)
Stripping ratio	SR < 2.5 (L-SR)	SR = 2.5–5.0 (LI-SR)	SR = 5.0–7.5 (I-SR)	SR = 7.5–10 (HI-SR)	SR > 10 (H-SR)
Differential unemployment rate	DUR > country average + 20% (H-DUR)	DUR = country average + 12–20% (HI-DUR)	DUR = country average + 5–12% (I-DUR)	DUR = country average + 0–5% (LI-DUR)	DUR < country average (L-DUR)

PR, potential resources; OG, ore grade; SR, stripping ratio; DUR, differential unemployment rate//H, high; HI, high intermediate; I, intermediate; LI, low intermediate; L, low

[2] Each document can contain information on more than one potential area.

[3] In this report, the use of the word ''resources'' does not involve any resource classifications according to standards in prospect reports or mining resources (e.g., NI 43-101, JORC or other codes) and is only used to reference potential mineralization in a prospective area.

group are directly associated with the placer deposits:

- *Deposit type (DT)* in relation to the morphology and position of the mineralized body in the sedimentary system. This variable reflects technical challenges or advantages in the exploitation of alluvial deposits, such as the method of material extraction (i.e., dry or wet), the maximum widths of exploitation, the presence of water in extraction by dry methods, or the need to use drilling and blasting to liberate the gold-bearing material;
- *Sediment column (SD)* associated with the presence of boulders or clays in the material conforming the deposit. The presence of boulders complicates material extraction on the mine, decreasing equipment reliability and real equipment usage. The clay reduces and/or complicates the recovery of gold during the concentration process, thereby increasing processing costs and/or decreasing operation returns;
- *Gold mineralization (GM)* in relation to the size and shape of gold particles in the deposit. Smaller sizes and/or elongated gold particles mean low recovery rates and high processing costs. However, large particles result in high nugget effect and operational safety risks;
- *Local water (LW)* associated with the availability/proximity of water sources for ore processing.

The second group incorporates qualitative variables related to the location of the prospective area[4]:

- *Land usage (LU)* associated with the current economic activity of the land at the prospective site. According to Chilean legislation, certain economic activities have preference use of land over the mining activities (e.g., residential, fruit/wine production and forestry), thus complicating the materialization of an alluvial gold project in specific locations;
- *Local communities (LC)* related to the distance from the prospective area to the closest town or village. Local communities determine the available workforce and services for the project, whereas groups opposed to the project within communities could hinder its development;
- *Mining property (MP)* associated with the availability of land without mining rights in the area;
- *Regional water (RW)* regarding general scarcity/available of water resources in the region, which could restrict water rights options for the project, even if this resource is physically available;
- *Weather (W)* in relation to climatic conditions that could affect the operations of a placer project, such as extreme aridity or intense rains or snowfalls.

Table 3 lists the alternatives for the qualitative variables used in the process. Figure 1 shows the location of the 67 placer gold prospects, and Table 8 shows the values/alternatives used in the prioritization for the 13 variables and the 67 mine sites ("Appendix").

It can be seen from Figure 1 that most of the sites/prospects identified in the study are located along the Coastal Cordillera in central and south-central Chile, from the Region of Coquimbo (Region IV, 300 km north to the capital city of Santiago) to the Region of Los Lagos (Region X, 1100 km south to Santiago). Therefore, most of these placer deposits share a similar tectonic setting, geological genesis and certain main characteristics.

Prioritization Process

Five stages were used to prioritize the placer gold sites/prospects: (1) preparation of information and generation of work proposals and presentations for a workshop with all the participants; (2) prioritization workshop; (3) calculation of preliminary results; (4) meetings to review preliminary results; and (5) adjustments/corrections and final results.

In stage 1, investigators compiled the information obtained from the bibliographic review and completed the missing information. Then, the material for the prioritization workshop was prepared, including the following proposals: definition of the objective (i.e., establishment of the first level in the hierarchical structure); alternatives for the hierarchical structure of the prioritization problem;

[4] Chile is administratively divided on 15 regions that are numbered from north to south, with the exception of Region XIV (previously included in the X Region) and Region XV (in the past belonging to the I Region).

Table 3. Evaluation alternatives for qualitative variables

Variables	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5	Alternative 6
Deposit type	Current terraces (CT)	Hanging terraces (HT)	Paleo-channel (PC)	Beach placers (BP)		
Sediment column	No boulders/no clay (NB/NC)	No boulders/clay (NB/C)	Boulders/no clay (B/NC)	Boulders/clay (B/C)		
Gold mineralization	Thick/sub-rounded (T/S)	Thick/laminar (T/L)	Intermediate/sub-rounded (I/S)	Intermediate/laminar (I/L)	Fine/sub-rounded (F/S)	Fine/laminar (F/L)
Local water	Close (C)	Intermediate (I)	Distant (D)			
Land usage	Residential (R)	Forestry (F)	Agricultural (A)	River bed/beach/federal (RB/B/F)		
Local communities	Close (C)	Distant (D)				
Mining property	Free (F)	Expired or negotiable (E/N)	In force (IF)			
Regional water	VIII region southward (VIII +)	VI and VII regions (VI/VII)	IV and V regions (IV/V)	III region northward (III −)		
Weather	XI and XII regions (XI/XII)	VIII to X regions (VIII/X)	IV to VII regions (IV/VII)	III region northward (III −)		

evaluation scales for quantitative variables; and definition of alternatives for qualitative variables associated with geographic location.

Stage 2 involved the prioritization workshop, which began with a short training on the formation and characteristics of placer gold deposits, as well as on the processes and technologies associated with their exploitation. The objective was to ensure a minimum level of understanding on the specificities of this type of mining. Then, the declared objective and the proposed alternatives for the hierarchical structure were discussed. This involved an open debate and the suggestion of other alternatives not identified during pre-work. After that, the alternatives for each of the final criteria (i.e., last level of the hierarchical structure) were presented and explained, and so the participants created their own pairwise comparison matrices. Then, individual and partnered evaluations within the entire hierarchical structure provided all the inputs needed to calculate preliminary results and to complete a consistency analysis of the process. However, each participant can analyze information and make adjustments as deemed necessary, with final responses sent within a week after the end of the workshop.

Stage 3 consisted in involved processing of individual evaluations using a spreadsheet. Obvious inconsistencies were identified and corrected. Then, the results of the subproblems were calculated for the entire hierarchical structure and the global problem was assessed.

In stage 4, the results were discussed in two meetings among the participants. They corrected the identified inconsistencies or approved the changes made by the research team. Also, they vary their judgments on the distinct pairwise comparisons within the whole problem as deemed necessary. The meetings resulted in the final inputs for the process. In stage 5, the final results for the prioritization, together with indicators of process consistency, were obtained.

RANKING OF PLACER GOLD PROSPECTS IN CHILE

Hierarchical Structure

During the prioritization workshop, a discussion regarding the objective of the process was held. This discussion centered on the need to incorporate variables relative to business potential, exploitation viability and economic and social impacts of future implementation. Consequently, the final objective of the prioritization was defined as: ''To obtain a multicriteria indicator for the technical, economic and social viability of exploiting potential placer gold sites/prospects in Chile.'' This objective was used to initially propose three essential criteria—business potential, exploitation viability and socioeconomic impact. However, after a more in-depth analysis of the available information, and considering the ex-

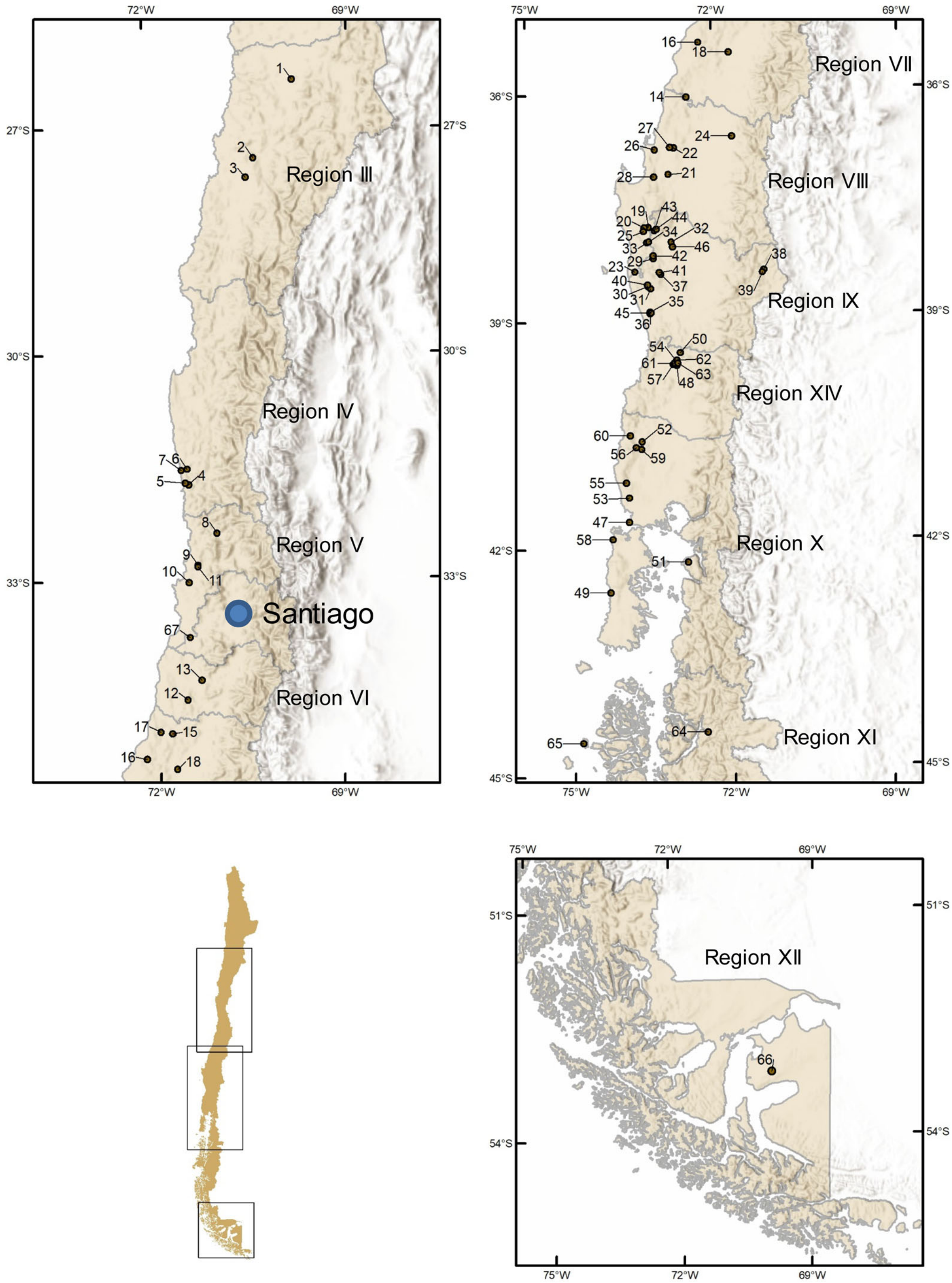

Figure 1. Location of ranked placer gold prospects in Chile. Identification numbers are the same as in Table 7.

pert's opinions, the concept of exploitation viability was divided into two groups: economic/technical feasibility and contextual viability.

Finally, the group defined the variables that were incorporated into each criterion (termed sub-criteria). At this point, some sub-criteria were eliminated based on redundancy (e.g., GDP per capita and opportunity zone were redundant to unemployment rate), quantification difficulties (e.g., environmental limitations) or currently active

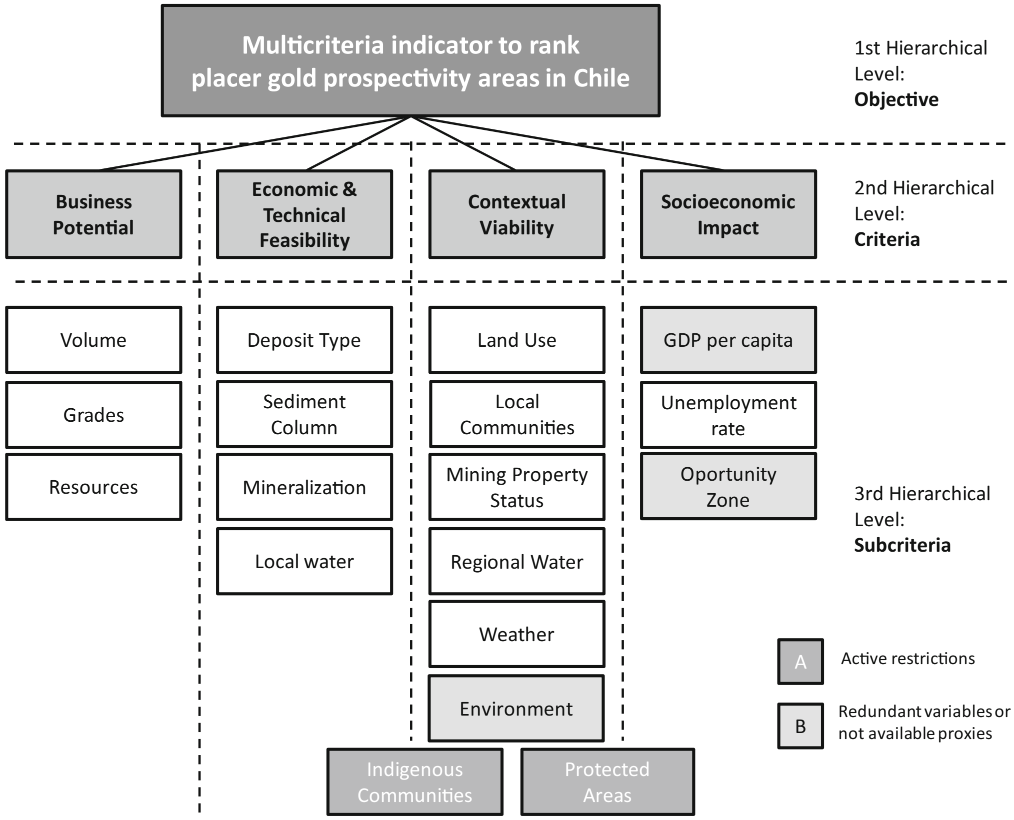

Figure 2. Hierarchical structure of the prioritization model for placer gold areas/prospects in Chile.

restrictions (e.g., location in protected areas or in/near to conflictive indigenous populations). As a result, the hierarchical structure presented in Figure 2 was obtained.

Prioritization and Logical Consistency

After defining a hierarchical structure, the AHP ensued with pairwise comparisons and the revision of their consistencies. In simple terms, this stage involved the construction of pairwise comparison matrices for the alternatives on the lowest level of the hierarchical structure, resulting in 13 matrices (i.e., one per sub-criterion), as well as for the higher hierarchical levels (four sub-criteria matrices and one matrix associated with the final objective of the process). Through this, the MCDM problem was transformed into 18 pairwise comparison matrices. However, as each expert had his own answers, there were a total of 180 matrices for analysis. The pairwise comparison matrices for quantitative criteria (i.e., sub-criteria PR, OG, SR and DUR) were previously established (40 matrices) and are detailed in Table 2. Therefore, the final prioritization stage involved the handling of 140 different matrices.

Because it is impractical to show all the matrices, only the most relevant and representative ones are presented here. Table 4 shows the comparison matrices for sub-criteria PR, OG, SC and GM for the responses of some of the experts, selected accordingly to those that were most representative of the final weighted values obtained based on Eqs. 4 and 5. Matrix vectors were weighted per expert and not the whole matrices. Therefore, there are no final results in terms of comparison matrices for each sub-criterion nor for each criterion, but only for the weight vectors $\bar{w}_y$.

Table 4 presents the following information: the matrices associated with four sub-criteria and their alternatives; the normalized eigenvectors (NEV) of the pairwise comparisons, which represents the weighted values per alternative within the sub-criteria; the weight vectors $\bar{w}_y$ obtained from the geo-

Table 4. Examples of comparison matrices for the principal sub-criteria: (A) potential resources, (B) ore grade; (C) sedimentary column; and (D) gold mineralization

	H-PR	HI-PR	I-PR	LI-PR	L-PR	NEV	$\bar{w}_y$
A. Potential resources (global)							
H-PR	1.00	1.29	1.80	3.00	9.00	0.36	0.36
HI-PR	0.78	1.00	1.40	2.33	7.00	0.28	0.28
I-PR	0.56	0.71	1.00	1.67	5.00	0.20	0.20
LI-PR	0.33	0.43	0.60	1.00	3.00	0.12	0.12
L-PR	0.11	0.14	0.20	0.33	1.00	0.04	0.04
CR	0.0%						

	H-OG	HI-OG	I-OG	LI-OG	L-OG	NEV	$\bar{w}_y$
B. Ore grade (global)							
H-OG	1.00	1.29	1.80	3.00	9.00	0.36	0.36
HI-OG	0.78	1.00	1.40	2.33	7.00	0.28	0.28
I-OG	0.56	0.71	1.00	1.67	5.00	0.20	0.20
LI-OG	0.33	0.43	0.60	1.00	3.00	0.12	0.12
L-OG	0.11	0.14	0.20	0.33	1.00	0.04	0.04
CR	0.0%						

	NB/NC	NB/C	B/NC	B/C	NEV	$\bar{w}_y$
C. Sedimentary Column (expert no. 2)						
NB/NC	1.00	5.00	3.00	9.00	0.55	0.61
NB/C	0.20	1.00	0.33	7.00	0.03	0.04
B/NC	0.33	3.00	1.00	9.00	0.28	0.20
B/C	0.11	0.14	0.11	1.00	0.14	0.15
CR	15.4%					

	T/S	T/L	I/S	I/L	F/S	F/L	NEV	$\bar{w}_y$
D. Gold Mineralization (expert no. 6)								
T/S	1.00	2.00	3.00	3.00	9.00	9.00	0.40	0.38
T/L	0.50	1.00	2.00	3.00	3.00	5.00	0.23	0.23
I/S	0.33	0.50	1.00	3.00	5.00	5.00	0.18	0.19
I/L	0.33	0.33	0.33	1.00	3.00	2.00	0.09	0.11
F/S	0.11	0.33	0.20	0.33	1.00	7.00	0.07	0.06
F/L	0.11	0.20	0.20	0.50	0.14	1.00	0.03	0.03
CR	22.8%							

CR, consistency ratio; NEV, normalized eigenvector

A and B—PR, potential resources; OG, ore grade; H, high; HI, high intermediate; I, intermediate; LI, low intermediate; L, low

C—NB/NC, no boulders/no clay; NB/C, no boulders/clay; B/NC, boulders/no clay; B/C, boulders/clay

D—T/S, thick/sub-rounded; T/L, thick/laminar; I/S, intermediate/sub-rounded; I/L, intermediate/laminar; F/S, fine/sub-rounded; F/L, fine/laminar

metric mean of responses for all experts in each sub-criterion; and the consistency ratios. Table 4A and B shows global matrices for the quantitative sub-criteria ‘‘potential resources’’ and ‘‘ore grade.’’ These alternatives were evaluated together by all the experts in the workshop, which agreed the evaluation scale of Table 1 (see also Table 2). Hence, these matrices are completely consistent (CR = 0.0%) and the normalized eigenvector is equal to the vector $\bar{w}_y$. Table 4C and D presents specific expert responses to the sub-criteria ‘‘sediment column’’ (expert no. 2) and ‘‘gold mineralization’’ (expert no. 6). Both experts were selected as best representing the average results obtained by applying the geometric mean to all the responses (i.e., where the normalized eigenvector was similar to the vector $\bar{w}_y$). It is important to remark that while these matrices are slightly inconsistent (CR > 10%), all matrices used in the process (i.e., 180 matrices) were consistent or slightly inconsistent, which is acceptable according to the literature.

Similarly, Table 5 shows the most representative comparison matrices for the four criteria, including their normalized eigenvectors, corresponding vectors $\bar{w}_y$ and the consistency ratios. As

Table 5. Examples of comparison matrices for principal criteria: (A) business potential; (B) economic/technical feasibility; (C) contextual viability; and (D) differential of unemployment rate

	PR	OG	SR	NEV	$\bar{w}_y$
A. Business potential (expert no. 4)					
PR	1.00	2.00	4.00	0.55	0.53
OG	0.50	1.00	4.00	0.34	0.31
SR	0.25	0.25	1.00	0.11	0.15
CR	5.2%				

	DT	SC	GM	LW	NEV	$\bar{w}_y$
B. Economic/technical feasibility (expert no. 9)						
DT	1.00	0.20	0.20	5.00	0.12	0.14
SC	5.00	1.00	1.00	7.00	0.42	0.34
GM	5.00	1.00	1.00	7.00	0.42	0.35
LW	0.20	0.14	0.14	1.00	0.04	0.18
CR	12.3%					

	LU	LC	MP	RW	W	NEV	$\bar{w}_y$
C. Contextual viability (expert no. 3)							
LU	1.00	2.00	0.50	1.50	5.00	0.25	0.20
LC	0.50	1.00	0.25	0.33	2.00	0.10	0.14
MP	2.00	4.00	1.00	1.50	4.00	0.36	0.36
RW	0.67	3.00	0.67	1.00	5.00	0.24	0.22
W	0.20	0.50	0.25	0.20	1.00	0.06	0.08
CR	5.7%						

	H-ΔUR	HI-ΔUR	I-ΔUR	LI-ΔUR	L-ΔUR	NEV	$\bar{w}_y$
D. Differential of unemployment rate (global)							
H-ΔUR	1.00	1.29	1.80	3.00	9.00	0.36	0.36
HI-ΔUR	0.78	1.00	1.40	2.33	7.00	0.28	0.28
I-ΔUR	0.56	0.71	1.00	1.67	5.00	0.20	0.20
LI-ΔUR	0.33	0.43	0.60	1.00	3.00	0.12	0.12
L-ΔUR	0.11	0.14	0.20	0.33	1.00	0.04	0.04
CR	0.0%						

CR, consistency ratio; NEV, normalized eigenvector

A—PR, potential resources; OG, ore grade; SR, stripping ratio

B—DT, deposit type; SC, sediment column; GM, gold mineralization; LW, local water

C—LU, land usage; LC, local communities; MP, mining property; RW, regional water; W, weather

D—ΔUR, differential unemployment rate; H, high; HI, high intermediate; I, intermediate; LI, low intermediate; L, low

can be seen, the matrices are consistent or slightly inconsistent, and the normalized eigenvectors do not vary significantly with the weighted vectors determined by the geometric mean of the expert's opinions. Table 5A shows that the most relevant variable for business potential is the ''potential resources'' (i.e., the quantity of contained gold in the deposit). It represents more than 50% of this criterion. ''Ore grade'' also has a significant effect (> 30%), whereas ''stripping ratio'' is the least relevant on business potential. Regarding economic/technical feasibility (Table 5B), the sub-criteria ''sediment column'' and ''gold mineralization'' have the greatest impacts, representing close to 35% each. For the contextual viability (Table 5C), the status of the ''mining property'' comprised a little more than a third of the weight, whereas the variables for ''land use,'' ''local communities'' and ''regional water'' vary between 22% and 14%.

Finally, in Table 6 the comparison matrix for the final objective of the prioritization process is given, as well as the respective consistency ratio and weighted vector. Business potential and economic/technical feasibility represent nearly 80% of the

Table 6. Example of comparison matrix for final objective

	BP	ETF	CV	SEI	NEV	$\bar{w}_y$
Multi-criteria indicator to rank placer gold prospects in Chile (expert no. 1)						
BP	1.00	1.50	2.00	4.00	0.41	0.40
ETF	0.67	1.00	1.00	3.00	0.26	0.37
CV	0.50	1.00	1.00	3.00	0.24	0.15
SEI	0.25	0.33	0.33	1.00	0.09	0.08
CR	0.9%					

CR, consistency ratio; NEV, normalized eigenvector; BP, business potential; ETF, economic and technical feasibility; CV, contextual viability; SEI, socioeconomic impact

multi-criteria indicator, leaving close to 20% for the other factors related to location, contextual and surrounding interactions.

In each of the cases, not only the matrix comparison values for the most representative expert of the group are given, but normalized eigenvectors and weighted vectors by the geometric mean are also shown. The results presented here consider a weighted geometric mean calculated using a 60%/40% ratio between the research group answers and outside/invited expert's responses.

Calculation of Results from the Prioritization Process

Once the pairwise comparison matrices were constructed and reviewed for logical consistency, the AHP was applied to calculate the weights for the alternatives, sub-criteria and criteria across the entire hierarchical structure of the MCDM problem. Ten distinct results were obtained, one per expert. Furthermore, these results were combined by calculating the weighted geometric mean, thus providing distinct group of results. Figures 3, 4 and 5 summarize the principal findings.

Figure 3 shows the range of results based on the responses of the 10 experts, one per sub-criterion. Shown are the minimum and maximum values, the range between the 20th and 80th percentile, and the arithmetic average. Furthermore, the final weight per sub-criterion is incorporated using the weighted geometric mean considering a 60% weight for DIM-UC research team and 40% for the external experts. The sub-criteria ‘‘stripping ratio,’’ ‘‘deposit type,’’ ‘‘sediment column’’ and ‘‘gold mineralization’’ have extreme values far outside the average and geometric means. However, the central ranges (i.e., 20th to 80th percentiles) are notably constrained. The rest of the sub-criteria present expected behaviors. It is important to highlight that the weighted geometric means do not significantly differ from the simple averages of the responses. The exception occurs with the ‘‘deposit type’’ variable, in which the mean is out of the central range due to one response that was highly discordant from the rest of the group.

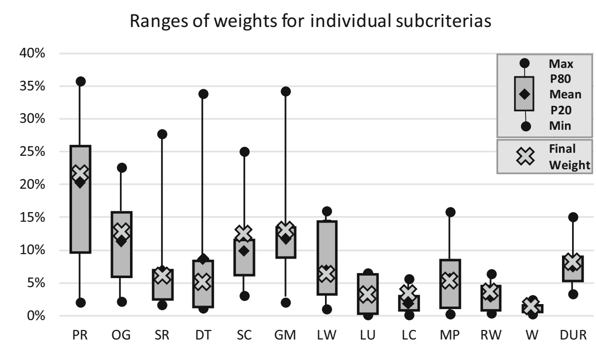

Figure 3. Weight ranges for individual sub-criteria. Abbreviations: PR, potential resources; OG, ore grade; SR, stripping ratio; DT, deposit type; SC, sediment column; GM, gold mineralization; LW, local water; LU, land usage; LC, local communities; MP, mining property; RW, regional water; W, weather; DUR, differential unemployment rate.

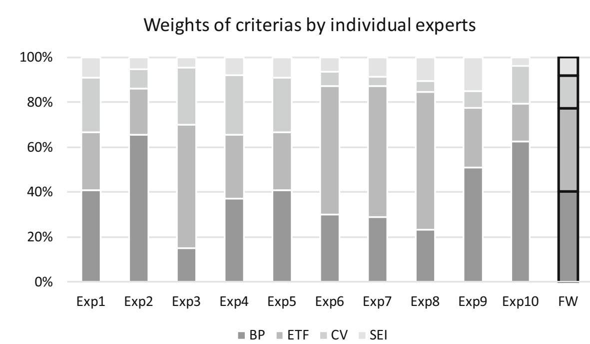

Figure 4. Criteria weights according to individual experts. Abbreviations: Exp_i, expert i; BP, business potential; ETF, economic and technical feasibility; CV, contextual viability; SEI, socioeconomic impact; FW, final weight.

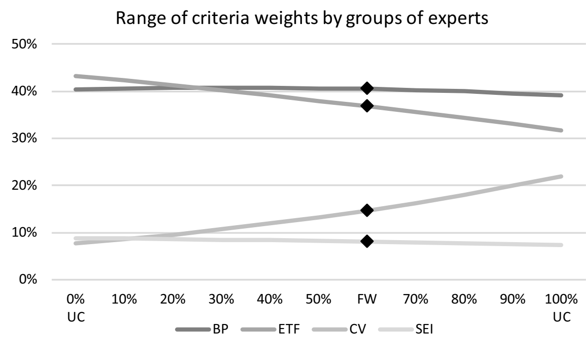

Figure 5. Criteria weight ranges for groups of experts. Abbreviations: BP, business potential; ETF, economic and technical feasibility; CV, contextual viability; SEI, socioeconomic impact; FW, final weight; UC, Universidad Católica.

Figure 4 presents the weights of the four criteria obtained from the 10 experts, as well as the final result from the weighted geometric mean. The experts from Enami (Exp6 to Exp8) gave high relevance to technical aspects, whereas Cochilco's specialists (Exp9 and Exp10) placed business potential at over 50%. The DIM-UC experts had a more diverse assessment, in line with their different areas of expertise.

Figure 5 shows the shares for the four criteria within a range of weights for the geometric mean, considering the participation of the DIM-UC researcher team on a scale from 0% to 100%. Worth highlighting is that business potential and socioeconomic impact shares remain fairly stable, close to

Table 7. Ranking of placer gold prospects in Chile

No.	Prospect	Region	BP	TV	OV	SEI	PI	Ranking
51	Prospect 51	X	0.35	0.30	0.12	0.08	0.85	1
23	Prospect 23	VIII	0.30	0.37	0.11	0.03	0.80	2
33	Prospect 33	IX	0.39	0.28	0.07	0.04	0.78	3
19	Prospect 19	VIII	0.33	0.21	0.12	0.08	0.74	4
25	Prospect 25	VIII	0.20	0.34	0.11	0.08	0.73	5
5	Prospect 5	IV	0.32	0.28	0.09	0.03	0.73	6
30	Prospect 30	IX	0.35	0.25	0.08	0.03	0.71	7
6	Prospect 6	IV	0.32	0.26	0.09	0.03	0.70	8
35	Prospect 35	IX	0.17	0.37	0.13	0.03	0.70	9
34	Prospect 34	IX	0.19	0.37	0.10	0.04	0.70	10
21	Prospect 21	VIII	0.28	0.26	0.11	0.04	0.69	11
47	Prospect 47	X	0.32	0.24	0.12	0.01	0.68	12
37	Prospect 37	IX	0.27	0.25	0.12	0.03	0.67	13
24	Prospect 24	VIII	0.35	0.20	0.07	0.04	0.67	14
20	Prospect 20	VIII	0.28	0.19	0.12	0.08	0.67	15
45	Prospect 45	IX	0.26	0.25	0.12	0.03	0.66	16
50	Prospect 50	XIV	0.35	0.13	0.13	0.04	0.66	17
31	Prospect 31	IX	0.25	0.28	0.11	0.03	0.66	18
65	Prospect 65	XI	0.29	0.24	0.11	0.01	0.65	19
39	Prospect 39	IX	0.29	0.19	0.11	0.04	0.64	20
7	Prospect 7	IV	0.29	0.25	0.07	0.03	0.63	21
44	Prospect 44	IX	0.33	0.13	0.12	0.04	0.63	22
36	Prospect 36	IX	0.19	0.28	0.13	0.03	0.62	23
4	Prospect 4	IV	0.32	0.20	0.08	0.03	0.62	24
54	Prospect 54	XIV	0.30	0.21	0.07	0.03	0.61	25
53	Prospect 53	X	0.29	0.16	0.13	0.03	0.60	26
56	Prospect 56	X	0.30	0.17	0.07	0.06	0.60	27
48	Prospect 48	XIV	0.33	0.13	0.08	0.04	0.59	28
62	Prospect 62	XIV	0.34	0.16	0.07	0.03	0.59	29
63	Prospect 63	XIV	0.22	0.25	0.07	0.04	0.59	30
61	Prospect 61	XIV	0.20	0.25	0.09	0.04	0.58	31
66	Prospect 66	XII	0.29	0.16	0.11	0.01	0.57	32
55	Prospect 55	X	0.35	0.10	0.07	0.04	0.57	33
59	Prospect 59	X	0.27	0.16	0.13	0.01	0.57	34
42	Prospect 42	IX	0.16	0.28	0.12	0.01	0.57	35
49	Prospect 49	X	0.22	0.24	0.09	0.01	0.56	36
32	Prospect 32	IX	0.28	0.16	0.08	0.03	0.55	37
29	Prospect 29	IX	0.19	0.22	0.12	0.01	0.54	38

Table 7. continuede

No.	Prospect	Region	BP	TV	OV	SEI	PI	Ranking
41	Prospect 41	IX	0.16	0.25	0.10	0.03	0.54	39
38	Prospect 38	IX	0.18	0.19	0.12	0.04	0.53	40
52	Prospect 52	X	0.29	0.16	0.07	0.01	0.53	41
22	Prospect 22	VIII	0.20	0.19	0.11	0.03	0.53	42
16	Prospect 16	VII	0.13	0.26	0.11	0.03	0.52	43
2	Prospect 2	III	0.33	0.11	0.06	0.03	0.52	44
12	Prospect 12	VI	0.10	0.26	0.13	0.03	0.52	45
18	Prospect 18	VII	0.13	0.27	0.10	0.01	0.51	46
40	Prospect 40	IX	0.16	0.25	0.07	0.03	0.51	47
60	Prospect 60	X	0.24	0.17	0.09	0.01	0.51	48
10	Prospect 10	V	0.21	0.17	0.09	0.03	0.50	49
46	Prospect 46	IX	0.22	0.17	0.07	0.03	0.49	50
43	Prospect 43	IX	0.18	0.13	0.12	0.04	0.48	51
8	Prospect 8	V	0.24	0.12	0.09	0.03	0.48	52
9	Prospect 9	V	0.18	0.14	0.12	0.04	0.48	53
67	Prospect 67	XIII	0.19	0.16	0.12	0.01	0.48	54
28	Prospect 28	VIII	0.17	0.18	0.10	0.03	0.47	55
11	Prospect 11	V	0.19	0.14	0.12	0.03	0.47	56
27	Prospect 27	VIII	0.16	0.16	0.10	0.03	0.44	57
57	Prospect 57	XIV	0.19	0.13	0.07	0.04	0.44	58
64	Prospect 64	XI	0.14	0.15	0.14	0.01	0.44	59
58	Prospect 58	X	0.10	0.24	0.09	0.01	0.43	60
26	Prospect 26	VIII	0.17	0.12	0.11	0.03	0.43	61
13	Prospect 13	VI	0.15	0.14	0.05	0.04	0.39	62
1	Prospect 1	III	0.13	0.13	0.08	0.03	0.37	63
3	Prospect 3	III	0.16	0.13	0.06	0.03	0.37	64
14	Prospect 14	VII	0.13	0.08	0.12	0.03	0.36	65
15	Prospect 15	VII	0.13	0.11	0.10	0.01	0.34	66
17	Prospect 17	VII	0.13	0.09	0.11	0.01	0.34	67

BP, business potential; ETF, economic and technical feasibility; CV, contextual viability; SEI, socioeconomic impact; PI, priority index

40% and 8%, respectively. Interestingly, the DIM-UC team gave greater relevance to contextual variables, contrasting with the external experts who privileged economic/technical feasibility over business potential.

Finally, the results were applied to each of the prospects identified during the bibliographic review. This resulted in a priority index for each of them that varies from 0 to 1. Then, the list of sites was ordered from highest to lowest index, creating a ranking for placer gold prospects in Chile.

Table 7 shows the priority index and ranking of each site/prospect, as well as the values for the four prioritization criteria. As can be seen, 10 prospects presented a priority index above 0.70, representing 15% of the total. These sites have high business potential and/or positive economic/technical feasibility, and their locations could be seen in Figure 6. In contrast, 18 prospects had a general result below 0.50, mainly due to having poor business potential and technical restrictions.

Application of Results for the Efficient Allocation of Public Funds

Once the results were obtained, they were used (together with the geographic localization of the sites) to define the sites that should be reviewed on the ground. The objective of this part of the project was to corroborate, by field-based activities, the bibliographic information for the most interesting prospects. Depending on the ease of access and terrain difficulties, the original plan was to conduct evaluations in 12–18 mine sites. However, the prioritization permitted a better allocation of public funds, avoiding its use to review non-attractive prospects and making efficient the field-trips logistics. Ultimately, 28 prospects were visited during the course of six campaigns. Only 14 of the 20 most interesting prospects were reviewed, as three were already known by the members of the team and three are located in areas that would have involved high costs. Additionally, four areas included within

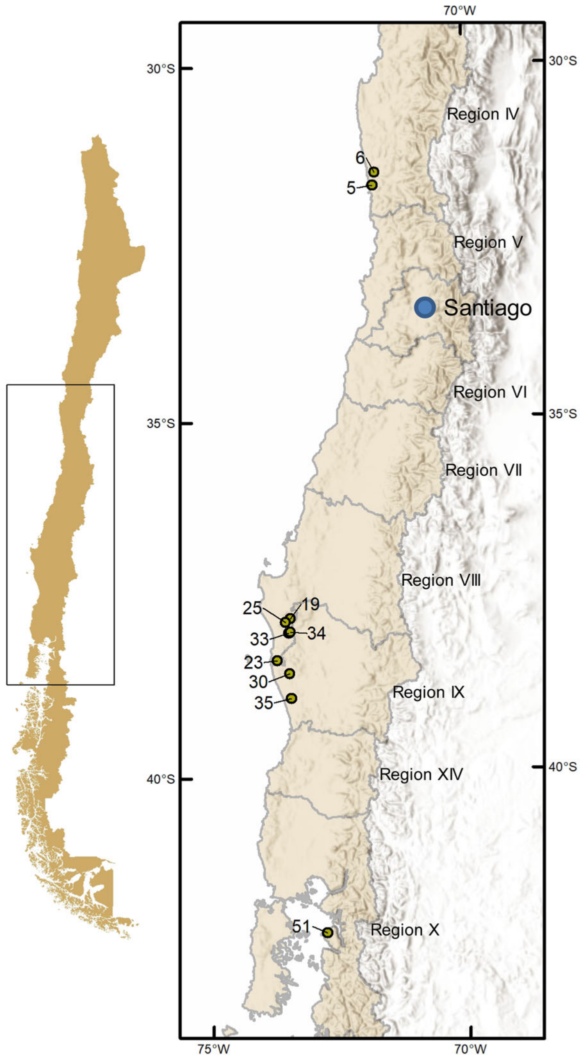

Figure 6. Location of the 10 best ranked placer gold prospects in Chile, as listed in Table 7.

the last 15 places in the ranking were visited to take advantage of proximities with high interest prospects, showing good (previously not recognized) potential. This efficient planning contributed to improve the final outcome of the project.

DISCUSSION AND CONCLUSIONS

The prioritization of prospects for subsequent mineral exploration and mining development is a complex problem that involves distinct technical, economic, social and environmental aspects (Ford et al. 2015). In the case of placer gold sites/prospects in Chile, existing information is spread across several sources and only partially covers the variables that are critical to decision making from government and/or private companies. The AHP-based methodology presented here permits, using quantitative variables and expert judgments, to rank the known prospective sites for placer gold deposits in Chile.

Despite the growing importance of numerous variables related to project execution (e.g., regulatory, environmental and community-related issues; Shen et al. 2015; Sobczyk et al. 2017), the results show that the business potential and economic/technical issues continue to be determinant for selecting areas to carry out more advanced mineral reconnaissance (40% and 37% of weights in the final decision, respectively). The answers from the experts show that potential resources (measured in terms of contained ounces of gold) and estimated ore grades (as grams per cubic meter) are the most relevant indicators for the attractiveness of a placer gold prospect. Other technical variables like sediments composition and gold characteristics play a significant role, together representing more than a third on the selection of an area respect to others. In contrast, contextual aspects only represent less than a quarter on the decision to choose a placer prospect for early exploration activities. In other words, in mining it is essential to first identify whether there is a business and then determine whether it can be properly developed (Jara 2017).

This study also shows that the inclusion of experts with different expertise enriches the analysis and does not significantly distort the final outcomes of the prioritization process. Individually, the answers can differ significantly, but as a group most responses fall into small ranges. Moreover, when weights among experts are changed, the relevance of the most important criteria (business potential) seems almost unaffected.

Finally, the use of MCDM tools is relevant when assessing the attractiveness of a mine site or a specific area for further exploration, particularly when efficient allocation of public funds for exploration activities is committed. Moreover, this kind of approach can be applied to prioritize the resources for basic and/or advanced public geoscience programs. In the case of Chile, the application of AHP methodology coupled with geographic information systems (GIS) can be useful to: (a) assess the potential of undiscovered placer gold deposits and (b) to prioritize the tasks and products of the national geological program of the national geological survey (Gildemeister et al. 2018).

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APPENDIX: VALUES/ALTERNATIVES OF VARIABLES USED IN THE PRIORITIZATION MODEL FOR PLACER GOLD PROSPECTS IN CHILE

See Table 8.

Table 8. Values/alternatives of variables used in the prioritization model for gold placer prospects in Chile

No.	Prospect	Region	PR (1)	OG (2)	SR (3)	DT (4)	SC (5)	GM (6)	LW (7)	LU (8)	LC (9)	MP (10)	RW (11)	W (12)	ΔRU (13)
1	Prospect 1	III	32	0.50	–	CT	B/C	IS	D	RB/B/FL	D	E/N	III –	III –	7.6
2	Prospect 2	III	24,113	5.00	7.0	CT	B/C	IL	D	RB/B/FL	D	IF	III –	III –	5.6
3	Prospect 3	III	322	1.00	1.0	HT	B/C	IS	D	RB/B/FL	D	IF	III –	III –	5.6
4	Prospect 4	IV	388,027	0.90	–	HT	B/C	TS	D	F	C	E/N	IV/V	IV/VI	9.3
5	Prospect 5	IV	101,275	0.90	–	CT	B/NC	TS	C	RB/B/FL	C	E/N	IV/V	IV/VI	9.3
6	Prospect 6	IV	549,778	0.57	–	CT	B/NC	TS	I	RB/B/FL	C	E/N	IV/V	IV/VI	9.3
7	Prospect 7	IV	64,301	0.20	–	BP	NB/NC	FS	C	RB/B/FL	C	IF	IV/V	IV/VI	5.3
8	Prospect 8	V	36,170	0.45	–	CT	B/NC	FS	D	RB/B/FL	C	E/N	IV/V	IV/VI	7.1
9	Prospect 9	V	4437	0.69	0.15	CT	B/NC	IL	D	RB/B/FL	C	F	IV/V	IV/VI	10.4
10	Prospect 10	V	14,468	2.80	4.60	CT	B/NC	IL	I	RB/B/FL	C	E/N	IV/V	IV/VI	9.1
11	Prospect 11	V	1286	6.40	7.0	CT	B/NC	IL	D	RB/B/FL	C	F	IV/V	IV/VI	9.3
12	Prospect 12	VI	129	0.40	–	CT	B/NC	TS	I	RB/B/FL	C	F	VI/VII	IV/VI	5.8
13	Prospect 13	VI	5144	0.10	–	CT	B/NC	IL	D	R	C	IF	VI/VII	IV/VI	12.5
14	Prospect 14	VII	282	0.63	0.8	CT	B/C	FL	D	RB/B/FL	D	F	VI/VII	VII/X	6.7
15	Prospect 15	VII	442	0.86	1.0	CT	B/C	FL	I	RB/B/FL	C	E/N	VI/VII	VII/X	4.1
16	Prospect 16	VII	359	0.65	–	CT	NB/NC	FS	C	F	C	F	VI/VII	VII/X	7.4
17	Prospect 17	VII	424	0.60	2.0	HT	B/C	FS	D	F	C	F	VI/VII	VII/X	3.8
18	Prospect 18	VII	965	0.60	–	HT	NB/NC	IL	C	RB/B/FL	C	E/N	VI/VII	VII/X	3.3
19	Prospect 19	VIII	28,936	4.00	5.7	CT	NB/C	IS	C	RB/B/FL	C	E/N	VIII +	VII/X	22.6
20	Prospect 20	VIII	13,503	3.00	6.0	CT	B/C	IS	C	RB/B/FL	D	E/N	VIII +	VII/X	22.6
21	Prospect 21	VIII	10,610	3.00	6.0	HT	NB/NC	FS	C	RB/B/FL	C	E/N	VIII +	VII/X	10.7
22	Prospect 22	VIII	2572	4.00	5.0	HT	B/NC	IS	I	RB/B/FL	C	E/N	VIII +	VII/X	9.6
23	Prospect 23	VIII	10,288	4.00	3.0	HT	NB/NC	TS	C	RB/B/FL	C	E/N	VIII +	VII/X	9.2
24	Prospect 24	VIII	57,871	15.00	41.0	HT	NB/NC	FS	D	F	C	IF	VIII +	VII/X	10.9
25	Prospect 25	VIII	563	3.50	5.0	CT	NB/NC	TS	I	RB/B/FL	C	E/N	VIII +	VII/X	22.6
26	Prospect 26	VIII	1608	2.00	3.0	CT	B/C	FS	I	RB/B/FL	C	E/N	VIII +	VII/X	9.6
27	Prospect 27	VIII	1157	1.20	0.67	CT	NB/C	IS	D	F	D	E/N	VIII +	VII/X	9.6
28	Prospect 28	VIII	1182	1.75	4.3	CT	B/NC	FS	C	F	C	E/N	VIII +	VII/X	9.4
29	Prospect 29	IX	2411	7.50	5.3	HT	B/C	TS	I	F	C	F	VIII +	VII/X	3.4
30	Prospect 30	IX	57,871	50.00	21.0	CT	B/C	TS	C	RB/B/FL	C	IF	VIII +	VII/X	9.2
31	Prospect 31	IX	3255	10.00	4.2	CT	NB/C	TS	C	RB/B/FL	C	E/N	VIII +	VII/X	9.2
32	Prospect 32	IX	19,290	6.00	7.0	CT	NB/C	FL	C	RB/B/FL	C	IF	VIII +	VII/X	8.7
33	Prospect 33	IX	64,301	10.00	3.5	CT	NB/C	TS	C	F	C	IF	VIII +	VII/X	10.9
34	Prospect 34	IX	1254	3.00	5.2	CT	NB/NC	TS	C	F	C	E/N	VIII +	VII/X	10.9
35	Prospect 35	IX	328	1.70	4.0	CT	NB/NC	TS	C	RB/B/FL	C	F	VIII +	VII/X	8.4
36	Prospect 36	IX	1929	12.00	6.8	CT	NB/C	TS	C	RB/B/FL	C	F	VIII +	VII/X	8.4
37	Prospect 37	IX	19,290	2.00	3.0	CT	B/C	TS	C	F	C	F	VIII +	VII/X	8.3
38	Prospect 38	IX	9002	0.80	1.0	CT	B/NC	IL	C	RB/B/FL	C	E/N	VIII +	VII/X	13.4
39	Prospect 39	IX	1,302,105	0.45	2.0	CT	B/NC	IL	C	RB/B/FL	C	E/N	VIII +	VII/X	13.4
40	Prospect 40	IX	322	620.00	30.0	PC	B/NC	TS	C	F	C	IF	VIII +	VII/X	9.2
41	Prospect 41	IX	643	40.00	19.0	PC	B/NC	TS	C	F	C	E/N	VIII +	VII/X	8.3
42	Prospect 42	IX	965	7.50	24.0	CT	NB/C	TS	C	F	D	F	VIII +	VII/X	3.4
43	Prospect 43	IX	1350	2.00	1.0	CT	NB/C	FL	I	F	D	F	VIII +	VII/X	10.9
44	Prospect 44	IX	33,758	2.00	2.3	CT	NB/C	FL	I	F	D	F	VIII +	VII/X	10.9

Table 8. Values/alternatives of variables used in the prioritization model for gold placer prospects in Chile

No.	Prospect	Region	PR (1)	OG (2)	SR (3)	DT (4)	SC (5)	GM (6)	LW (7)	LU (8)	LC (9)	MP (10)	RW (11)	W (12)	ΔRU (13)
45	Prospect 45	IX	9645	30.00	–	PC	B/NC	TS	C	F	C	F	VIII +	VII/X	8.4
46	Prospect 46	IX	6963	4.90	8.0	CT	NB/C	FS	C	F	C	IF	VIII +	VII/X	8.7
47	Prospect 47	X	514,412	0.80	–	BP	NB/NC	FL	C	RB/B/FL	C	E/N	VIII +	VII/X	3.8
48	Prospect 48	XIV	53,049	1.10	5.0	CT	NB/C	FL	I	RB/B/FL	C	IF	VIII +	VII/X	13.3
49	Prospect 49	X	12,777	0.75	–	BP	NB/NC	FL	C	RB/B/FL	D	IF	VIII +	VII/X	3.4
50	Prospect 50	XIV	114,778	3.00	14.3	CT	B/C	FL	C	RB/B/FL	C	F	VIII +	VII/X	11.1
51	Prospect 51	X	128,603	1.00	–	CT	NB/NC	IS	C	RB/B/FL	D	E/N	VIII +	VII/X	5.9
52	Prospect 52	X	281,319	0.35	–	CT	NB/C	FL	C	F	D	IF	VIII +	VII/X	–
53	Prospect 53	X	38,581	1.20	2.6	CT	NB/C	FL	C	RB/B/FL	C	F	VIII +	VII/X	5.9
54	Prospect 54	XIV	31,829	3.00	20.0	CT	NB/C	IS	C	F	C	IF	VIII +	VII/X	9.6
55	Prospect 55	X	385,809	3.00	20.0	HT	NB/C	FL	D	F	C	IF	VIII +	VII/X	11.9
56	Prospect 56	X	25,078	1.20	2.2	CT	NB/C	FS	C	F	D	IF	VIII +	VII/X	15.2
57	Prospect 57	XIV	3086	1.20	5.0	CT	NB/C	FL	I	F	D	IF	VIII +	VII/X	13.3
58	Prospect 58	X	1286	0.40	–	BP	NB/NC	FL	C	RB/B/FL	C	IF	VIII +	VII/X	3.5
59	Prospect 59	X	19,290	2.00	4.0	CT	NB/C	FL	C	RB/B/FL	C	F	VIII +	VII/X	–
60	Prospect 60	X	21,219	0.33	–	CT	NB/C	FS	C	RB/B/FL	C	IF	VIII +	VII/X	–
61	Prospect 61	XIV	14,468	0.30	–	CT	NB/NC	FL	C	RB/B/FL	D	IF	VIII +	VII/X	13.3
62	Prospect 62	XIV	87,772	2.60	7.8	CT	NB/C	FL	C	F	C	IF	VIII +	VII/X	9.6
63	Prospect 63	XIV	6945	1.60	4.0	CT	NB/NC	FL	C	F	D	IF	VIII +	VII/X	13.3
64	Prospect 64	XI	64	1.00	5.0	CT	B/C	FS	C	RB/B/FL	D	F	VIII +	XI/XII	2.0
65	Prospect 65	XI	96,452	0.30	–	BP	NB/NC	FL	C	RB/B/FL	D	E/N	VIII +	XI/XII	2.0
66	Prospect 66	XII	308,647	0.48	–	CT	NB/C	FL	C	RB/B/FL	C	E/N	VIII +	XI/XII	4.7
67	Prospect 67	XIII	82.9	3.00	6.5	HT	B/NC	IS	D	F	C	F	VIII +	IV/VI	4.5

Column DT, deposit type; BP, beach placer; HT, hanging terrace; PC, paleo-channel; CT, current terraces; Column SC, sediment column; NB/C, no boulders/clay; NB/NC, no boulders/no clay; B/C, boulders/clay; B/NC, boulders/no clay; Column GM, gold mineralization; FS, fine/sub-rounded; IL, intermediate/laminar; IS, intermediate/sub-rounded; TL, thick/laminar; TS, thick/sub-rounded; Column LW, local water; C, close; D, distant; I, intermediate; Column LU, local usage; A, agricultural; F, forest; R, residential; RB/B/FL, river bed/beach/federal land; Column LC, local communities; C, close; D, distant; Column MP, mining property; E/N, expired/negotiable; F, free; IF, in force; Column RW, regional water and Column W, weather; III −, III Region Northward; IV/VII, IV to VII Regions; IV/V, IV and V Regions; VI/VII, VI and VII Regions; VIII +, VIII Region Southward; VIII/X, VIII to X Regions; XI/XII, XI and XII Regions

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