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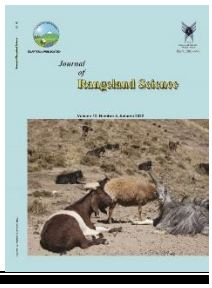

Research and Full Length Article:

Indigenous Knowledge of Shepherds in Determining the Flammability of Vegetation: A case study of Khalkhal Semi-Steppic Rangelands of Iran

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Abstract. The indigenous knowledge of shepherds about the different components of the plant fuel, ways of their classification and their contribution to fire behavior helps range managers to understand fire and effective management of the rangelands. The present research aims to document the indigenous knowledge of shepherds in this regard. For this purpose, a semi-structured interview in 2020 with 17 shepherds of semi-steppe rangelands of Khalkhal in northwestern Iran was performed and data were analyzed by the note-taking method and the categorization method. Given the knowledge of shepherds, plants were categorized into three groups of carriers, retardant, and burnable. They consider the morphological traits, type and composition of vegetation, climatic factors and physiography to be effective in creation and spread of fire. Shepherds' controlled fires are carried out with the aim of removing thorny plants to increase the length of the green period of the plants, to graze more livestock, to increase the income, to destroy the old seedlings and to rejuvenate the rangeland. Uncontrolled and deliberate fires are conducted with the aim of destroying state property, protesting against fines, unhealthy competition and conflicts between individuals, which reduce the winter forage of livestock and land grabbing. The time required for the rehabilitation of the rangelands was expressed after 6-7 years after fire. Practical suggestions could be used in participatory management system (shepherds and officials from natural resources management) for controlling fuel density using different grazing systems.

Key words: Turbulence, Traditional ecological knowledge, Fire management, Plant sensitivity, Herders

Introduction

The fire behavior is affected by climate, topography, anthropogenic factors, and particularly, the properties of the fuel material at the time of the fire occurrence (Fuller, 1991; Coughlan, 2014). Fuel materials are function of vegetation cover in a region such as the composition of species, conditions and structure (Baeza *et al*., 2006; Duff *et al*., 2012; Schunk *et al*., 2017). Fire management before, during and after the occurrence requires understanding the fuel properties, which has the most effect in this part (Keane *et al*., 2001; Rossa, 2017). Uncontrolled fire in ecosystems causes damage to shepherds' life, plant cover, and ecosystems services. The proper management of ecosystems to minimize these costs requires some features of the fuel material and their role in fire behavior to be understood (Bradstock *et al*., 2012; Thompson *et al*., 2013).

Fire regimes are natural and cultural entanglement phenomena resulting from interaction between humans and the environment (Bowman *et al*., 2011; Coughlan and Petty, 2012). Specifically for cattle raisers, fire is often a management tool and most efficient way to control wooden species and keep plant cover suitable for animal grazing (Johansson *et al*., 2012). The local fire knowledge is defined as knowledge, beliefs, and related fire-related practices that are used by the indigenous population for specific purposes (Huffman, 2013). In fact, the knowledge accumulated is the skills and techniques of a particular society that has gained direct interaction with the environment (Bicker *et al*., 2004; Verlinden and Dayot, 2005).

In traditional knowledge, the process of fire in vegetation is positively related to protecting the landscape, maintaining vegetation and maintaining biodiversity (Garnett *et al*., 2018; Reyes-García *et al*., 2019). This requires a better understanding of the ecological role of traditional management practices of using fire in shaping and maintaining landscapes (Hobbs, 2009; Bugalho *et al*., 2011). Moreover, it is essential to understand traditional management practices to be used to design policies that provide sustainable social and ecology systems (De Aranzabal *et al*., 2008). In such a way that ignores traditional approaches for Christian use of fire in mountainous regions has led to the accumulation of fuel materials and increased fires in some parts of Europe (San Emeterio *et al*., 2016). The importance of giving indigenous knowledge and trying to integrate it with formal knowledge creates a holistic view of the protection of natural resources. For this reason, in some countries, indigenous people have a key share in policy formulation and intervention in the development of fires (Welch and Coimbra, 2019).

Previous literature on localized knowledge in fire focused on different topics such as the use of shepherds in the landscapes change (Coughlan, 2014), fire sustainability in traditional communities (San Emeterio *et al*., 2016), traditional knowledge about the fire and its consequences in fire management (Cogos, *et al*., 2019), traditional knowledge about the use of fire (Steen-Adams *et al*., 2019). Despite these efforts, awareness of the role of indigenous knowledge in the determination of plant fires, categorization of fuel components, and their role in the fire system are still unknown.

One of the areas under threat of controlled and uncontrolled fires is Khalkhal semi-steppe rangelands, located in the south of Ardabil province Iran. According to available statistics, during a ten-year period (2010-2019), 256 fires occurred in rangelands, mostly by indigenous people with different goals and motives (unreported information from Khalkhal Natural Resources Department). Although according to the laws of the National Forests and Rangelands Organization, burning rangelands is considered illegal, but fires have occurred

repeatedly in recent years in different parts of these rangelands. However, little is known about the historical relationship between the livelihood of the people of the Khalkhal semi-steppe rangelands and the fire. As a result, the need to better understand how to use fire and its techniques and how to manage fuel resources should be examined. The present research aims to document the indigenous knowledge of the shepherds in the field of fire detection, distribution of fuel components and their role in the fire of rangelands and understanding how shepherds perceive and classify vegetation fuel materials in their traditional knowledge system?

Materials and Methods

Study area

The Khalkhal rangelands in the south of Ardebil province, Iran is located in the geographic coordinates of, 48°32′ to 48°34 ′ E and 37°26′ to 37°37′N across the height of 1900 to 2720 m above sea level (Fig. 1). The mean annual precipitation in the region is about 360 mm (15.7% in March and 1.7% in August as the highest and the lowest rainfall during the year) and the average annual temperature is 9.7°C (Max 35.5°C and Min -35.5°C) (Ghorbani *et al*., 2012). Climate of regions is semi cold by Emberger method. More than 95% of this county is mountainous area, the depth and type of soil vary (Ghorbani *et al*., 2012, Ghorbani *et al*., 2017). In the rangelands of Khalkhal, due to the cold weather and multiple frosts in high altitudes, the agriculture is very limited. Due to the area's economic infrastructure, which is mainly based on dairy, land use is common as rangelands in this region. The rangeland area is approximately 7813.45 ha, the livestock number is 3795 heads. The area's livestock consists of about 75% sheep, 20% goats and about 5% cattle, respectively. The grazing season in rangelands started from May to November. Generally, four vegetation types have been reported:

1) Astragalus,

2) Astragalus-Thymus- *Onobrychis cornuta*,

3) Astragalus- Perennial grasses,

4) *Onobrychis cornuta-Astragalus*- Perennial grasses.

The dominant vegetation cover consists of different plant functional types as;

Grasses: *Festuca ovina*, *Bromus danthonia*, *B. tectorum*, *B. tomentellus*, *Hordeum marinum*, *H. bulbosum*,

Forbes: *Verbascum speciosum*, *Thymus kotschyanus*,

Bushes: *Onobrychis cornuta*, *Astragalus microcephalus*, *A. aureus*, *A. compactus*, *Acantholimon giliatii*, *A. acerosum*.

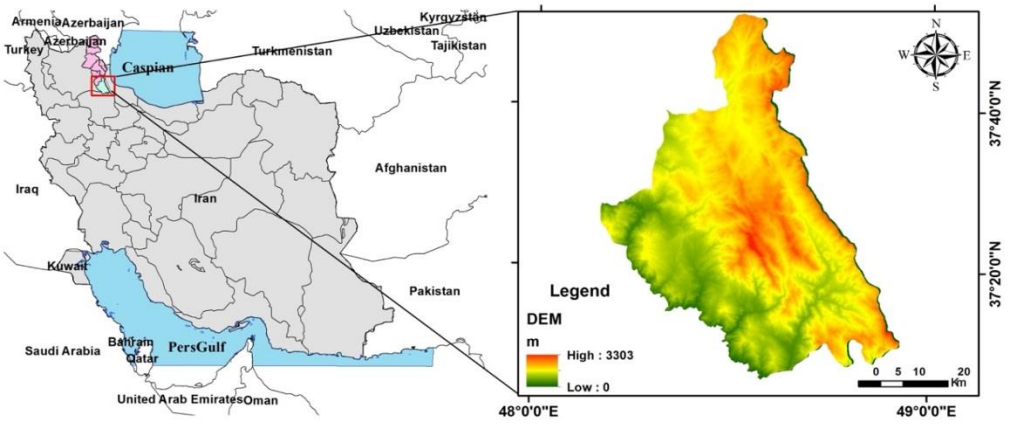

Fig. 1. Location of Khalkhal region in Ardebil province, Iran

Sampling Method and Data Collection

The data were collected in field survey and deep and semi-structured interviews with shepherds. The present study was conducted on 17 regional participants (those as shepherds or having history of shepherds' activities) as talked narrators and informers. 17 shepherds were selected from all 153 available shepherds. We found shepherds who had a good knowledge about fire. So, we considered the rangeland where the fire broke out. For this purpose, we used the snowball method to find shepherds with fire knowledge. Finally, after interviewing 17 shepherds, no new material was added to the scope of our findings. So, the sampling was based on 17 shepherds. Also, almost no other shepherds with information and knowledge pertaining fire were found. They were given interviews in solitary confinement.

The interviews were conducted individually and face-to-face. The researchers were accompanied by a local person as an intermediate between the interviewer and the interviewee. As shepherding was a man profession and men were always involved in controlled and uncontrolled firing, interviewees were selected among them.

This research was done by both illiterate and informed individuals who were in the researcher and residents of the area. Since, the professional shepherds are men and the fire of the rangelands is controlled and uncontrolled by these people. Therefore, the selected Interviewees were ranged in age from 32 to 79, with an average age of 54, of whom 10 were illiterate and 5 had low literacy (at the level of reading and writing), one person had a postgraduate degree, one person had a bachelor's degree. These people had been involved in shepherding since their childhood and adulthood were completely familiar with plant species and their firing behavior in the region. At the beginning of the interview, the interviewee was asked the following question: could you please tell about firing in rangelands?

The most questions were asked from interviewees were:

- Which plant species is highly fire prone?
- Is there a difference between plants based on their role in the fire?
- Which factors the vulnerability of plant species to fire are most dependent on?
- How do you classify plants based on their fire sensitivity?
- How does fire spread?
- Are morphological characteristics of plants related to fire?

After each period when the interviewee's talk was finished, the questions of ambiguous and unfamiliar subjects were again questioned. Some issues that contained new content were asked by the person in various forms. The interviewee was permitted to speak out completely. The interviews lasted from 90 to 120 minutes. All interviews were digitally recorded by audio recording. An informed consent was obtained to follow the instructions of the International Federation of Anthropology (ISE, 2006) and the General Data Protection Act (GDPR).

In the next step, the information obtained was filtered from different methods of note taking and key concepts were extracted based on the purpose of the research. In this study, one of the methods of data collection was participatory observation. To do so, the authors visited the shepherds' homesteads and plant habitats in the region. Authors participated in collecting plants for firing and the information pertaining plant identification and their firing characteristics as well as plant behavior in response to fire and fire effects were gathered. The applicable firing techniques and skills were documented with the help of some shepherds. In this order, researchers did not only interview the interviewees but also participated in the firing process and had the chance to better understand the conditions in which firing was executed.

Results

The shepherds as for each of the vegetation species considered a role and sensitivity in the fires and their unique classifications. Each of the plants in the environment around them in their oral and nominal culture was different based on the behavior of plants in fire. These components have been classified and defined in such a way that for the most shepherds, they have well-known concepts. In all categories that will continue, the definition and writing of classifications are based on the direct narration of the shepherds, and the authors have avoided any kind of personal opinion in writing definitions and concepts.

1. Differences of vegetation and their role in the fire

Incendiary and carrier of fire: Given the information obtained from the interviews, the grasses are incendiary and carrier of fire. In response to the role of plants in the fire, they stated that Poaceae cuts the fire continuously and evenly (Fig. 2). Poaceae dries quickly and transfers the fire between the plants in the plant composition, thus burning the whole area in the fire (Fig. 2c). In the case of Poaceae, more emphasis is placed on the phrase "the same gasoline burns and does not last in the fire."

Fire retardant: According to the information available to plants such as *Acantholimon giliatii*, which is known as shepherd's pillow, this plant keeps fire itself (Fig. 2b). According to the shepherds' observations, this plant smokes for a few days after the fire, bigger and greener the plant, the more it keeps the fire inside the plant. This plant is very dense and has no room at all to breathe and ignite. In fact, the plant does not catch fire at all, "it just smokes and keeps the fire under the ashes. *Verbascum speciosum* can keep the fire at the bottom of its stem for several days (Fig. 2a). In the past, it was used as a torch. "If it does not get extinguished by the wind, we can fire everywhere with this plant; however, it is only the bottom of the stem which burns late and other parts of the plant burn quickly and finish fast. In the past, because of the thickness of the stem's bottom and existence of hairy leaves, it was used as a torch".

Fuels in the fire*:* Plants belonging to *Astragalus* genus and other shrub species which have thick stems burn longer in the fire (Fig. 2d). "*Astragalus* catches the fire easier and burns longer *in* the fire". "Shrub species belonging to Astragalus are used as fuel material for fire. Every time "you want to start the fire, you have to burn the *Astragalus*."

Fig. 2. Plant differences in terms of their role in fire a and b; Fire retardant c; Incendiary and carrier of fire d; Fuels in the fire

2. Morphological characteristics of plants and its relationship with fire

Existence of thorns in plants: One of the reasons for burning plants is having many thorns. The thorn of the plant burns like gasoline. The reason for burning thorns is dryness and fullness of this part of the plant was stated. One of the reasons that species are more concerned about fire among shepherds is the thorniness of these plants. *Astragalus* burns faster because it has thorns. Among the species of *Astragalus*, only the species that are in the form of bushes are considered. "Because Black *Astragalus (Astragalus microcephalus)* is spiny, it burns longer. In the past when there was no oil, this plant was used to make the fire". The fire initiates from plant thorns and spiny parts of the plant, "the thorns of the plant burns first and then, other parts of the plant start burning". Shepherds were showing the burned plants where the stems were left and the branches and leaves were completely altered to ashes to prove their point (Fig. 3).

Fig. 3. Stems of *Astragalus microcephalus* left after the fire

Fruit or seed shape of the plant: Dry and small seeds are effective in burning the plant and plants that haven't dried fruit burn less.

The presence of fluff and cotton in plants: The presence of fluff on plant organs, especially on the leaves and cotton-shaped parts of plants (*Stachys lavandulifolia*, *Marrubium astracanicum*, *Salvia chloroleuca*, *Phlomis olivieri*) were a negative factor in the flammability of plants. Cotton-shaped parts burn hard like fluff, but end late (longer than hairless leaves).

Type and shape of the crown: wide cover and distance between branches are negative factors in the firing of the plants and the transferring of fire between them. Because White *Astragalus (Astragalus compactus)* "has a wide cover and its branches have distance from each other", it does not burn perfectly. "This plant among other Gavan is famous for not burning perfectly".

Life form: shepherds believe that plants (*Acantholimon giliatii*) growing near the ground (cespitose plants) will fire harder. In this case, the air does not enter the plant which makes the plant burn. For them, the best way to burn plants is to be semi-erected and to have a contiguous crown.

Stem type: Having thick and woody stems and branches is one of the most important morphological characteristics in generating heat and the durability of fire. Shepherds use *Astragalus* plants to make fire and tea. As they stated, these species are more durable in fire. *Astragalus* species produces a lot of heat due to having "thick stems". The *Onobrychis cornuta* plant burns well if it is dry, but it is not used for lighting fires and brewing tea. Dried stems of *Astragalus* are used as firewood to heat the house and brew tea. Because plants of the Poaceae family do not have wooden stems, do not produce good heat. In the face of other plants, such as Qalqan *(Cousinia sp.),* shepherds consider them to have no fuel value.

Leaf type: The type of leaf was introduced as one of the factors affecting firing of plants. Some species such as grasses have high flammability owing to their thin leaves which dry very fast. With regard to the forbs, shepherds stated "these species dry later and burn less". Therefore, based on shepherds' perception, having thin leaves and stems increase the sensitivity of these species to firing.

Secondary materials: Some plants burn with an explosion. Some species of *Astragalus* such as *Astragalus microcephalus* have a "chert chert sound" when they are oily.

3. Behavior of plants in fire

Burning mode: *Acantholimon* species burns very slowly. In this case, some local people have known it as heavy burns. This plant does not burn continuously, but when it burns, sometimes the flames subside and sometimes, the plant ignites. In This way of burning, the plant is accompanied by a lot of smoke. Some plants such as Poaceae family burn from top to bottom. The method of burning genus *Astragalus* is also different from other species. The various species of the genus *Astragalus* burn continuously with high temperatures. Other plants in the area are not classified in this group and it is believed that other plants are not worth burning.

Firing modes: Wind direction accelerates the fire. "Wind circulates in sloppy foothills". Hence, in foothills, plants burn more than smooth areas and plains". If the fire starts at sloppy foothills it continues to the mountain peak. Stoping fire in such conditions is possible only in areas with no vegetation cover.

Time required for plants to burn: Plants have different burning times depending on their structural characteristics. It takes about 20 minutes for a shrub to burn completely to ashes. Next in line are plants such as *Verbascum speciosum*. In contrast, the time required to burn a Poaceae species is about a few seconds.

Volume of fire: The amount of fire is a function of the height and volume of the

plant. Grass has nothing to burn, and because of its lack of height and volume, it produces less heat. Therefore, places where grass burns in the fire are less damaged. In contrast, shrub species are larger than other rangeland plants, and having "woody stems" generates a lot of heat, and therefore, the soil and other parts of the rangeland ecosystem are more damaged. Where there is a lot of *Astragalus*, the plant cannot grow well after the fire. For this reason, empty spots in the area are considered to be places where vegetation has been burned (Fig. 4).

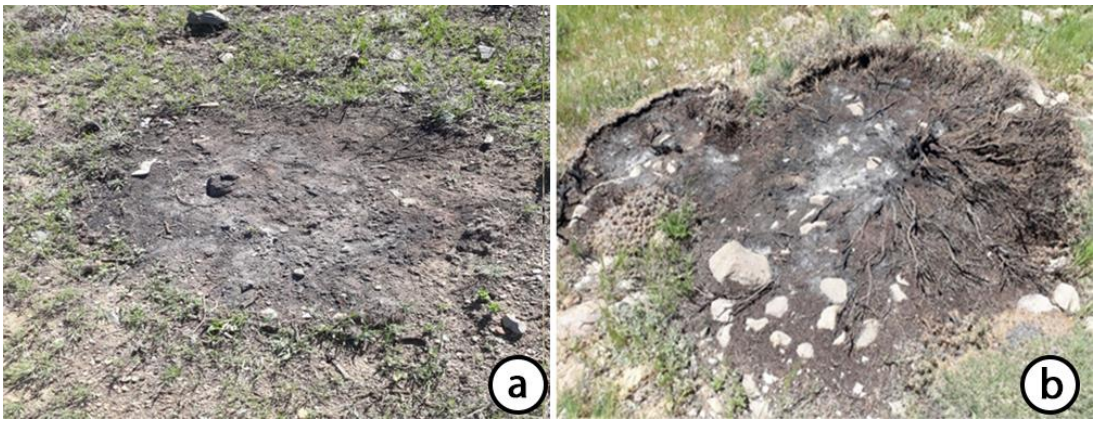

Fig. 4. a and b Remnant of Astragalus after the fire

4. Plant structure and composition in fire

Density: The distance between plants are an important factor in the spread of fire. One of the shepherds showed the association between plant density and fire development using his steps length. "If there are two *Astragalus* per each step, the fire is intense. If there are two *Astragalus* per two steps, the risk of fire development is less and finally, if there are two *Astragalus* per three steps, the fire does not move and transfer to other areas. *Astragalus* does not burn when they are not close to each other unless there are grasses in between".

Type of vegetation: Based on shepherds' point of view, the combination of grasses and *Astragalus* will lead to the highest sensitivity of firing. "Grasses burn very fast and *Astragalus* has higher durability in burning; consequently, the continuity of fire in rangelands will happen". On the other hand, fire is transmitted by grass to the other plants, which makes it difficult to control fires. The local people said that there has always been a fire in this area, but in recent years, the fire has increased due to the migration of villagers and the reduction of livestock in the area. In such a case, livestock does not compete with the vegetation of the area and many parts of the rangelands are always left without grazing or with light grazing.

5. Climatic and physiographic factors as driving forces in fire

Seasonal variations: Two seasons of wet (mid-autumn to mid-spring) and dry (mid-spring to mid-autumn) affect the fire process. So, most fires occur in the dry season, especially in July and August. Lack of rain and dry plants were the main seasonal stimuli. In spring, the ground and the plant are both wet.

Plant fire in the day and night: Many of rangeland plants burn more around noon or in the afternoon. If the plants in the rangelands catch fire during the day, the fire will continue at night. But the fire that starts at night is rarely in the area.

Moisture and dryness: The most important factor differentiating plant regarding their firing behavior is the amount of moisture in their parts. "When a plant is dry, it burns

better". Most shepherds declared that "when a plant is wet, it does not burn at all". As plants belonging to the Poaceae family dry faster, they have higher sensitivity to fire. Shepherds stated that "Being dry and having thin leaves and stems result in ease of plant burning". The amount of time required for stems, branches and leaves to dry out affects their firing. As *Onobrychis cornuta* "dries late, it burns less".

Rainfall: During rainfall, plants have less sensitivity against firing owing to up taking water and the higher moisture of their dry parts. "Whenever the rainfall occurs, plants do not burn because of wetness and the moisture". The stability of rainfall effect on plants is associated with regional climate condition. One of the shepherds stated "plants do not burn until one week after the rainfall approximately"

Wind: Wind affecting the drying of plant organs and litter causes the spread of fire. After the plants catch fire, the wind carries the fire away and catches fire everywhere. So, on windy days, the plants catch fire with just a spark and it becomes difficult to control. It is necessary to put out the fire in order to prevent from burning the plant so that from their point of view, in the fire, the direction of the wind is very important and determines the direction of the fire (Fig. 5). Wind is one of the effective factors in the loss of moisture after rain. If the wind blows after the rain, two or three days later, the plant dries up and burns easily.

Lightning: According to indigenous observations, range plants will not be fired by the heat of the sun or by the impact of lightning. In response to the question of how likely plants would fire from the heat of the sun and lightning. They said they have never seen such a thing before.

Fig 5. a and b the fire ascending to the peak of the mountains by the wind in khalkhal

Hills and plains: In this case, the existence of a board of large stones, barren lands or mane and lack of vegetation cover natural barriers in preventing fire spread. If there is no grass, the fire will be prevented.

Slope: the shape of the earth affects the fire of plants, and the plants growing on the slopes are more burning than in the smooth areas. On steep slopes the air flow is greater, if the range of fire falls on inclined slopes of the fire to the summit of the mountains. The motion and propagation of fire are also from the bottom to the top of the mountain. The fire doesn't move down as the wind blows to the peaks.

Aspect: Although some locals stated that the direction and the amount of slope have no effect on burning plants and fire. But some shepherds said that every side of the mountain that gets more sun burns more. Therefore, the southern direction is

indirectly considered to be more prone to fire.

6. Effective factors in fire

Reason for burning the rangelands: Shepherds, addicted people and burning straw and farms after farm harvesting their crops are some of the reasons behind the burning of rangelands. They start a fire to warm up and make tea; of course, a fire at the rangelands sometimes started by addicts who start lighting fires and smoking cigarettes around the roads and villages. According to some prior observations, farmers who try to develop their cultivated land by setting fire to straw and farms after harvesting their crops. They burn straw to seize more land, which burns plants around agricultural land and finally takes over the natural resources land.

The reasons behind rangeland fire: Four factors, a) the elimination of thorny species, b) the elimination of state property, c) protest against fines and d) clashes between the target people were mentioned. Removing thorny plants was introduced as one of the goals of rangeland firing. "Thorny plants bother the livestock and reduce our income". Vegetation belt from *Astragalus* is the border of governmental and private lands. "Wherever there is *Astragalus*, it belongs to the government, therefore, to grab governmental lands *Astragalus* must be destroyed". Some people declared their intention for firing the rangelands to be a protest reaction against being fined by the Natural Resources and Watershed Management Organization (NRWMO). "Whenever NRWMO fine us, we might burn their lands as a consequence". Some also mentioned the unhealthy competition people in order to destroy the forage of lands as a stimulating factor.

7. The rate of fire damage and time required for restoration the rangeland

Vegetation vulnerability to fire: Removal of shrubs such as *Astragalus* and prickly spores in fire is temporary (Fig. 6). When an *Astragalus* burns, it takes three or four years to grow, but it does not die. To eradicate the acorns, these plants must be uprooted. Plants with woody stems, if combined with vegetation, soil will be damaged. *Astragalus* produces a lot of heat when it burns and the soil turns black, which causes more damage to the ground. In fires, most plants such as *Astragalus* are temporarily destroyed and then, the grasses and broadleaf ones increase.

The time required for reconstruction: According to the results of interviews with pastoral shepherds who suffer from fire, after 6 to 7 years, it will be the same as before the fire. Native regeneration refers to the presence of pre-fire species in the plant composition. Based on their observations, the local plant communities started after 3 to 4 years. They stated that distinguishing between burnt places from non-burned places after another 7 years is not possible.

Fig. 6. a and b Sprouting of *Onobrychis cornuta* after fire

8. Opportunities and threats of the fire

Opportunities: According to the observations of the locals of the burned areas, after the first year, they grow very well and produce a lot of grass. In this case, the locals use the term "rejuvenation of rangelands" (Fig. 7). They consider the burning of old species as an important factor for the growth of green fodder used by livestock. After fire and regrowth of plants, the length of their green period increases compared to non-burned areas, the ground is freed so that plants can grow more easily. They justify their claim by showing the empty spaces created after the fire and eliminating species such as *Astragalus* and *Onobrychis cornuta*. Some species and other thorny plants are considered to be a factor in wounding the feet and muzzle of their animals and believe that the presence of these plants causes harm to them.

Threats: Some locals also stated that prickly species such as *Astragalus* on days when snow and rain occur during the cold season of the year are the only fodder available to animals, these plants soften when it rains and on the other hand, they are always present in the area than others. Plants are only present in the rangelands during the warm seasons of the year, so the species should not be burned. On the other hand, it is believed that thorny species are grazed by livestock such as goats.

Fig. 7. a) Long-lasting green rangelands under fire compare to b) non fire control

Discussion

As a whole, shepherds have extensive indigenous knowledge in understanding and classifying plants in terms of their role in the fire. In this classification, the species of incendiary and fire-carrying grass, plants such as *Acantholimon* and the stem of the *Verbascum speciosum* were classified as fire retardants, and species of invertebrates in the fire. Small grain plants such as grass usually produce standing dead fuels that dry out rapidly in response to low soil moisture and atmospheric moisture, causing combustion. Due to the density and abundance of grass, they are the most important factor in igniting and carrying fire in the region. Increase and accumulation of these species increase flammability and in some cases, it causes the fire to recur (Rossiter *et al*., 2003; Brooks *et al*., 2004).

While some shrubs with succulent stems increase moisture, they make the spread of fire more difficult (Brooks *et al*., 2004). Density and proximity to the ground reduce airflow inside the plant and prevent the plant from igniting. Some plant species burn less intensely than other plants by creating a humid microclimate (Slocum *et al*., 2003). In some plants such as

Verbascum speciosum, the presence of thick, moist and hairy leaves provides unfavorable conditions for plant flammability.

In a study by Vivian and Cary, (2011); Rafiee *et al*. (2015), Traits such as leaf type, thick cortex and canopy structure have been mentioned as fire resistant traits. The presence of woody stems in *Astragalus* plants causes high heat in the fire. These plants increase the amount of heat released per unit time, which increases the intensity of the fire (Brooks *et al*., 2004). Individual traits of plant species have caused their different role in fire; these traits can be used to predict the response of plants to fire and their classification.

As the shepherds' pointed out, characteristics such as Having many thorns, dried fruits, thin and dry stems and leaves and having chemical compounds (oily substance) inside the plant are important criteria in determining the sensitivity of plants to fire. Some plants are prone to flammability due to age or small leaves due to being prickly, having dried limbs in parts of the plant. Baeza *et al*. (2002) reported that the amount of moisture in live plants decreases with maturity and as a result, their flammability increases with age. Plant chemical compounds such as volatiles increase the flammability of plants and some compounds such as minerals reduce this ability (Brooks *et al*., 2004). Therefore, plant traits play an important role in determining the sensitivity and response of plants to fire and therefore can affect fire behavior.

The great amount of fuel materials is a result of the current management of these rangelands and is due to the abandonment of livestock. The migration of shepherds and the reduction of herders increase the dry fodder and litter in the region, which is an important factor in the fire. Accumulation of combustible material is one of the factors determining fire behavior (Keifer *et al*., 2006). Livestock grazing has the potential to significantly affect fire characteristics (Kerby *et al*., 2007; Waldram *et al*., 2008).

High concentrations of surface fuels may lead to unforeseen environmental consequences that conflict with management objectives (Busse *et al*., 2005; Knapp *et al*., 2011; Kreye *et al*., 2011). The purpose of determining the plant composition of the area is to achieve a suitable range of combustible material compounds to control the risk of fire with the least possible damage. From the shepherds' point of view, the combination of weeds and species creates the greatest fire sensitivity in any region. Due to the presence of grass and the amount of wood fuel (shrubs), the intensity of combustion in this type of plant composition is very high and the fire is stable.

Fuel substrates in terms of physical properties have a complex structure that is effective in fire behavior and in the choice of fire control methods. According to the shepherds, there is often a wind current on the sloppy foothills; as a result, the plants burn more compared to the flat places, and the process of movement and spread of fire is from the bottom to the top of the mountain. On a steep slope, the speed of fire increases (Dong *et al*., 2005). In this regard, Matthews *et al*. (2012) and Hoffmann *et al*. (2003) reported fires due to the topographic conditions of the region, climate change and fuels. Natural ecosystems often have a slope of change, and high levels of spatial and temporal changes occur in the composition of species and characteristics of fuels (Duff *et al*., 2012; Duff *et al*., 2013; Keane, 2016).

Therefore; in order to manage and control fires, moisture information, temperature, rainfall, speed and direction of wind specify the number of days that the rangelands may have to burn normally.

The shepherds of the region have gained the knowledge and reaction of the plants in the fire from various aspects through continuous monitoring of livestock in the rangelands, creating knowledge about the

importance of fire in improving the rangelands and eliminating plants that are not suitable from the farmer's point of view. They consider the burning of old species as an important factor for the growth of green fodder used by livestock. One of the main reasons for rangelands burning by pastors is the need to rejuvenate the rangelands and improve the availability of resources (Angassa and Oba, 2008; Welch and Coimbra, 2019; Butz, 2009).

As a result of burning of plants and the return of nutrients to the soil, it increases the fertility of the soil, which is why the length of the green period of plants increases. Burning plants also reduces competition between species, in which case some locals used the phrase "the earth is freed up so that plants can grow more easily. By increasing density of plant species in rangelands, due to the increase of prickly and non-edible species, their economic value and range capacity are affected and lead to reduced productivity and profitability of rangelands (Mugasi *et al*., 2000; Ayalew and Mulualem, 2018).

Removal of *Astragalus* and *Onobrychis cornuta* is a factor in eliminating state ownership. As for the species, they believe that wherever there is a species, it belongs to the government. Since rangeland fire is an illegal practice, it is necessary to amend the law and create conditions for controlling fires that target livestock farmers. Based on their observations, the locals stated that plant species such as *Astragalus* and *Onobrychis cornuta* re-form a significant part of the vegetation composition after 3 to 4 years. To prevent the increase of fuels and to control the area, prescribed fires are prescribed for 4 to 8 years. Practical suggestions could be:

a) Using participatory management system (shepherds and officials from natural resources management) for controlling fuel density through using different grazing systems;

b) Using prescribed designed firing based on traditional and scientific knowledge systems and

c) Adjustment of grazing time (seasonal and monthly) based on plant phenology and forage quality using both traditional and scientific knowledge systems.

Conclusion

Shepherds' perception in Khalkhal rangelands from the role of plants in firing is a unique classification which enables them in determination of plant flammability and firing characteristics. These definitions and classification suggest that fire for the shepherds is of great importance because their income depends on the rangelands fodder which in turn changes under the impact of fire. Plants have different characteristics based on their morphological characteristics in plant flammability, which can determine the sensitivity of plants to fire. Studying the firing characteristics of plants helps a deeper understanding of using fire through local people and efficient management of firing. This knowledge can be used as a basis for implementing fire management methods that enable sustainable livelihoods of ranchers. Documenting the local knowledge of the shepherds on the factors affecting fire can be used as an important information source in determining the intensity of fire and recognizing the behavior of fire alongside the formal knowledge. The shepherds believed increasing the number of livestock and creating a balance between livestock and rangeland production increases rangeland profitability and control of fuel materials.

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دانش بومی شبانان در تعیین آتش‌پذیری گیاهان: مطالعه موردی مراتع نیمه استپی خلخال- ایران

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چکیده. دانش بومی شبانان در مورد اجزای مختلف سوخت گیاهی، چگونگی طبقه‌بندی و نقش هریک از آنها در رفتار آتش به درک بهتر از آتش‌سوزی و مدیریت کارآمد مراتع کمک می‌کند. مطالعه حاضر به مستندسازی دانش بومی شبانان در این زمینه می‌پردازد. به همین منظور، مصاحبه نیمه ساختاریافته در سال ۱۳۹۹ با ۱۷ نفر از شبانان مراتع نیمه استپی خلخال در شمال غربی ایران صورت گرفت و داده‌ها از روش فیش‌برداری و مقوله بندی تحلیل شدند. طبق دانش شبانان گیاهان به لحاظ نقش در آتش‌سوزی به سه دسته حمل کننده، نگهدارنده و سوختنی تقسیم‌بندی می‌شوند. آنها ویژگی‌های ریخت شناسی، نوع و ترکیب پوشش گیاهی، عوامل اقلیمی و فیزیوگرافی را بر ایجاد آتش و گسترش آن موثر می‌دانند. آتش‌سوزی‌های کنترل شده شبانان با هدف حذف گیاهان خاردار برای افزایش طول دوره سبز بودن گیاهان، چرای بیشتر دام‌ها، افزایش درآمد، از بین رفتن نهال‌های پیر و جوان شدن مرتع انجام می‌شود. آتش سوزی‌های کنترل نشده و عمدی با هدف از بین بردن مالکیت دولتی، اعتراض به جریمه شدن، رقابت ناسالم و درگیری بین افراد است که باعث کاهش علوفه زمستانی دام‌ها و تصاحب اراضی مرتعی می‌شود. زمان مورد نیاز برای بازسازی مراتع بعد از آتش‌سوزی ۶ تا ۷ سال بیان شد. پیشنهاد عملی می‌تواند استفاده از سیستم مدیریت مشارکتی (شبانان و مسئولان مدیریت منابع طبیعی) برای کنترل تراکم سوخت از طریق استفاده از سیستم‌های مختلف چرا باشد.

کلمات کلیدی: آشفتگی، دانش سنتی اکولوژیک، مدیریت آتش، حساسیت گیاهان، دامداران