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PHYSIOGRAPHIC STUDY AND MONITORING CLIMATIC IMPACTS ON COLD DESERT KATPANA, SKARDU, PAKISTAN

RUMANA SIDDIQUI*, KANWAL JAVID[**], MUHAMMAD AMEER NAWAZ AKRAM[***]

[*]Department of Geography, University of the Punjab/ HEC, Pakistan
[**]Department of Geography, Government College University, Lahore, Pakistan
[***]State key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LEISMARS), Wuhan University, china
*Corresponding Author's Email: rumanasiddiqui5@gmail.com

ABSTRACT

The highest cold desert of the world is situated in the northern area of Pakistan. It is an epitome of beauty and wilderness lies at an elevation of 2,226 m above sea level, in the central valley of Gilgit-Baltistan, Skardu. It is a simple of peacefulness. Physiographic study and comparative mapping of Satpana desert has been a neglected area. This paper aims to fill this gap in literature by mapping Satpana desert and by producing its portfolio. Map of the study area is generated by using RS and GIS tools. For which, two images of Sentinel 2 data type, with 10m resolution has been downloaded from USGS Earth Explorer, for the years of 2015 and 2018. NDVI and SARVI indices are used to calculate vegetative and nonvegetative land cover area. The study shows that the total area of the desert is 9.4 square km. Dunes found in study area of Satpana cold desert are parabolic in shape, the average height of dunes is 2235m. It is concluded from the results that climate change is leaving its impact on this desert as its 0.74 sq. km area has been converted into vegetative land cover from barren land from 2015 to 2018. Although, it is a positive sign but presents the shift of cryospheric hazard zone due to atmospheric warming. The snow is melting at rapid pace due to increasing of temperature of the study area and its surrounded lofty snowy mountains in summer season. It disturbs the permafrost equilibrium and warn about the upcoming chain of reactions or atmospheric hazards.

KEYWORDS: Cold desert, cryospheric hazard, cold desert in Pakistan, highest altitude desert, GIS, NDVI, SARVI and portfolio of sand dunes.

INTRODUCTION

The spatial study of deserts has always been the focus for entire world because deserts cover an area of 41 percentage the earth land surface and almost 2 billion population of the world is living in them (Eason *et al.,* 2008). The fluctuation in the area of desert is prone to climatic changes and human activities (Sternberg *et al.,* 2015). The reduction and expansion in many deserts area like Gobi, Sahara, Thar and many other deserts have been portrayed in many researches' work around the world (Eason *et al.,* 1980 to 1990; Tucker *et al.,* 1991; Eason *et al.,* 2008; Jeong *et al.,* 2011; Sternberg *et al.,* 2015).

Tucker *et al.,* (1991) are revolutionized the study of the desertification and deduction of marginal changes in Sahara Desert based on biomass by using remote sensing (RS) tools in their investigation. Sternberg *et al.,* (2015) has used geographic information system (GIS) and RS techniques to investigate the changes in boundaries of Gobi cold desert, in China. They have also applied vegetative indices like Normalized Difference Vegetation Index (NDVI) and Aridity Index (AI) for the spatial mapping of Gobi Desert. Resent report of United Nations Development Program (UNDP, 2017) has shown that more than eighty percent area of Pakistan has been turned into semi-arid or arid land. These semi-arid and arid deserts have been studied by many researchers. The study was mainly on phytogeographical and desertification of hot desert of Pakistan specifically, Thar and Cholistan (Irshad *et al.,* 2007; Anjum *et al.,* 2010; Heshmati & Squires, 2013; Verstraete,1986). But the cold desert has been remaining neglected field of study. Pakistan is known for her highest altitude cold desert, Katpana (FFK, 2017; AKRSP, 2015).

Physiographic study and comparative mapping of Katpana desert has been a neglected area. Scientific identification of the cold desert is needed to be studied thorough geomorphological assessment, GIS and RS tools enable to any researcher to delineate its further detailed and make it a data driven document (Trabucco & Zomer, 2009; Karnieli *et al.,* 2013). Accurate segregation of desert boundaries is needed before discussing its physical features like sand dunes (Eason *et al.,* 1980 to 1990; Shoshany, 2012). Therefore, present research proposes to fill this gap in literature by mapping Katpana desert and by producing its present boundary map, portfolio and comparative mapping.

MATERIAL AND METHODS

Study area

The highest cold desert, Katpana is situated near Skardu, Pakistan. Katpana desert or locally known as Biama Nakpo (fig.1). It is found at an elevation of 7,303 feet above sea level. Because it lies in the rain shadow of the Himalayas, Katpana desert has a typical cold desert climate (Fameeda, 2016; PMD, 2015-19). The desert comprises large areas of sand dunes which are covered with snow in winter season. The average maximum and minimum temperature range is between of 27 °C and a minimum below −17 °C 19 (GBMD, 2019; PMD, 2019). The geographical coordinates of Katpana desert are 35.310522°N and 75.590747°E. The desert geographically lies between the Khaplu valley and Zanskar in Ladakh, but the main desert area is found in Skardu and Shigar valley. Skardu is the capital city of Gilgit Baltistan in the northern part of Pakistan, it is surrounded by China in north east and Kashmir in southeast, Tajikistan in north west and Afghanistan at its west (Sarina, *et al.,* 2008; Pakpedia

Encyclopedia Skardu, 2017). Gilgit Baltistan is geographically located in central Asia. The climate and life style of Gilgit Baltistan is more identical to central Asian countries than the south Asian countries (Fameeda, 2016); Pakpedia Encyclopedia Skardu, 2017)

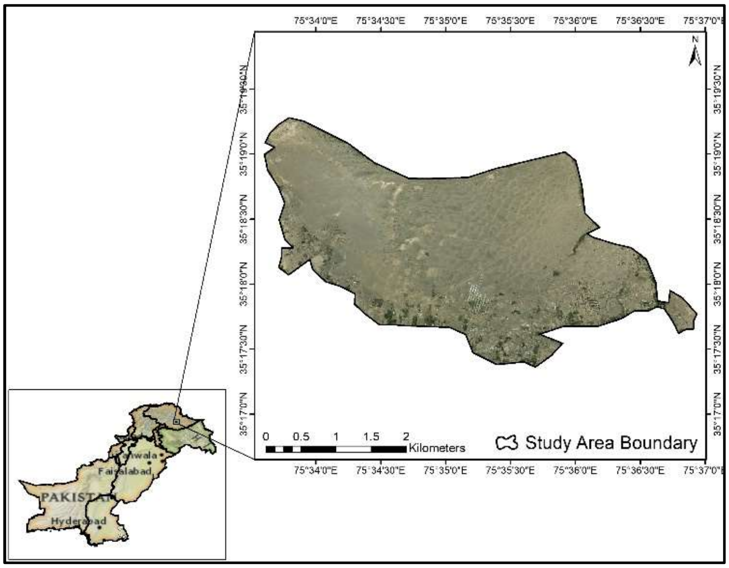

Figure 12. **Map showing study area Katpana desert, Skardu, Pakistan**

MATERIAL AND METHOD

The map of the study area (Katpana Desert) is generated by using RS and GIS tools. For which, multi-temporal RS data images of Sentinel 2 data type, with 10m resolution has been downloaded from USGS Earth Explorer, for the years of 2015 and 2018. The comparative study has been conducted to trace the changes in boundary of desert, which is based on vegetation indices i.e. NDVI and SARVI indices are used to calculate vegetative and nonvegetative land cover area. The results of these indices are further processed through statistical tools like comparison and correlation. This paper delineates the Katpana cold desert boundary. Topographic maps of deserts are produced to identify the fluctuation in the area of desert in three years, from 2015 to 2018.

Sentinel 2 data type, was employed to determine spatial detailed efficiently. Two images have been downloaded in the month of April 2019, from USGS Earth Explorer, for the said years. Remotely sensed data of vegetation cover in desert and satellite assess physiographic results are verified by conducting field survey. Geographic survey of Katpana desert has proven the usefulness of satellite evaluation and fortified the indication of vegetation cover in the Katpana (Sternberg *et al.,* 2008; Tachiiri *et al.,* 2011; Sternberg *et al.,* 2015).

NDVI is the most commonly used vegetation index in RS. Almost all type of flora shows sensitivity near-infrared spectral region. This index is suitable for the area with less flora. Vegetation cover ranging from minimum value of –1 to maximum value of +1 could be assessed by NDVI (Hao *et al.*, 2012).

$$\text{NDVI} = \frac{NIR - Red}{NIR + Red} \quad (1)$$

In spite of lessening topographic effects and showing good results for all type of vegetation cover by separating them from soil cover, NDVI is unable to eliminate atmospheric effects. To remove atmospheric effects, Atmospherically Corrected Indices are used i.e. Soil and Atmospherically Resistant Vegetation Index (SARVI) (Hao *et al.*, 2012; Zarco et al., 2013; Sternberg *et al.* 2015)

$$\text{SARVI} = \frac{RNIR-RRB}{RNIR+RRB} + L(1 + L) \quad \boldsymbol{L} = 5 \quad (2)$$

The results are fortified by applying composite NDVI with SARVI. Simple statistical analysis is employed to detect the correlation in the area of vegetation cover changes in desert, i.e. arid or semi-arid. The result of NDVI has proved robust when supported by SARVI index. NDVI observations are also compared with average data of temperature collected by available meteorological stations of Gilgit Baltistan.

Physiographic study of Katpana cold desert has also been conducted and portfolio of randomly selected sand dunes is produced. The width and height of the sand dunes is also measured through Google Erath Pro.

RESULTS AND DISCUSSION

NDVI and SARVI data show the reduction of the Katpana boundary from 2015 to 2018 (fig. 3,5) by increasing in the vegetation cover area. The results of NDVI and SARVI are detected a progressive decreasing trend in total desert area. It is found that 0.74 km^2 area of desert has been converted into vegetative area, during three years from 2015 to 2018. The present area of Katpana is 9.4 km^2 (Table 2) (Figure 1). Finding shows that greater variability has been observed at the marginal area of desert than in the central. 7.9 % has been converted into vegetated land cover area from non-vegetative land cover area (Fig.2-5), which is due the extreme weather conditions in study area. It is the positive of sign increasing moisture in the marginal soil of desert. Salik et al., (2015) claimed that extreme weather changes like rising temperature in summer is the main cause of melting glacier at a great rate. According to Sharma and Sharma (2008) water shortage has to face by Asian population by the end of 2050. On the other hand, melting and retreating of Himalayas' glaciers become the constant threat for their lives at the same time (Wong *et al.,* 2015). Wong *et al.,* (2015) and Zulfiqar, (2007) are offered similar point of view about the scarcity of water in near future. Cold deserts are very vulnerable for the global warming and cryospheric hazard, settlement expansion, change in river course and other developments in surrounding area. Furthermore, there is a strong correlation ($p \leq 0.01$) between the expansion of vegetative cover area and contraction in the area of desert bare soil. It is revealed that the results of NDVI has shown increase in the area of vegetation cover in the Katpana desert. This study identifies a contraction of the Katpana Desert from 2015 to 2018. The change deducted in land cover is 7.9 % within three years.

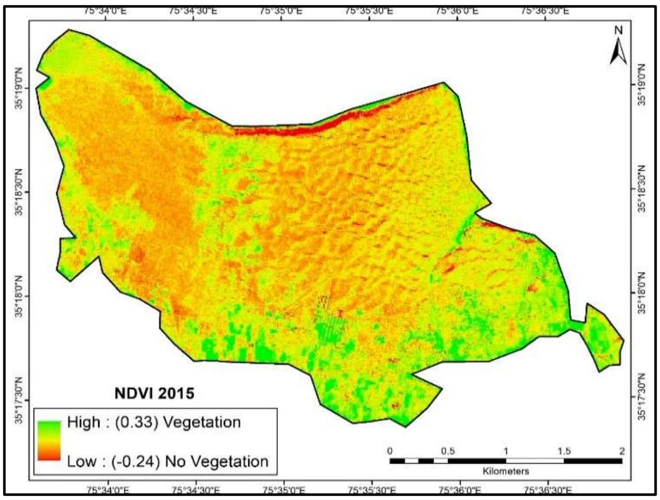

Figure 2. Map showing Normalized Vegetation Index (NDVI) of Katpana desert for the year 2015.

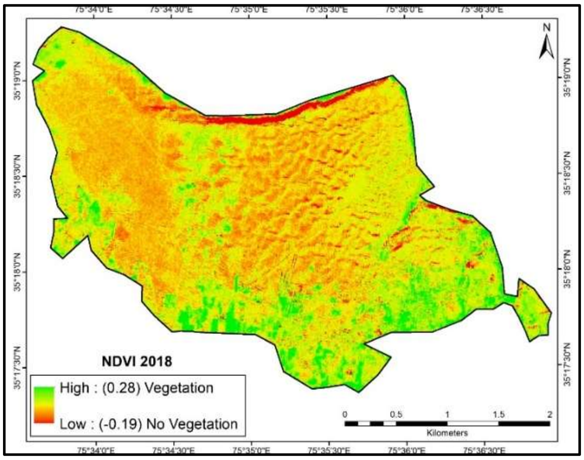

Figure 3. Map showing Normalized Vegetation Index (NDVI) of Katpana desert for the year 2018

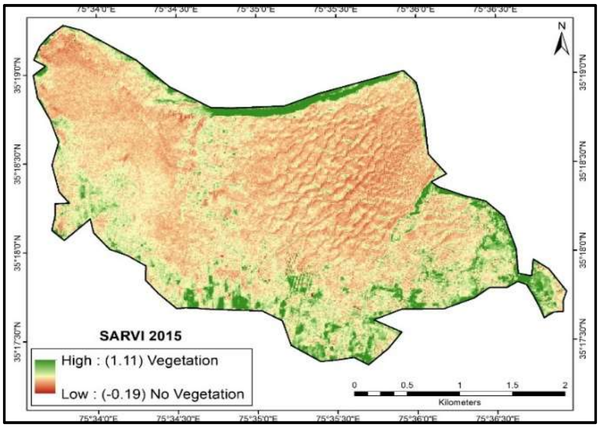

Figure 4. Map showing Soil and Atmospherically Resistant Vegetation Index (SARVI) of Katpana desert for the year 2015**.**

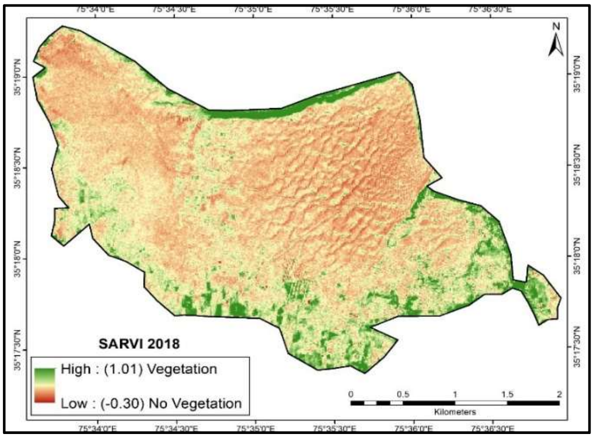

Figure 5. Map showing Soil and Atmospherically Resistant Vegetation Index (SARVI) of Katpana desert for year 2018.

Dunes Portfolio

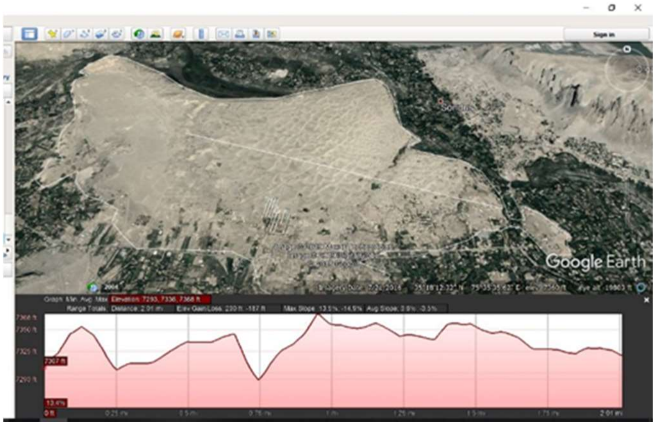

Figure 6. Dune Portfolio (DS1)

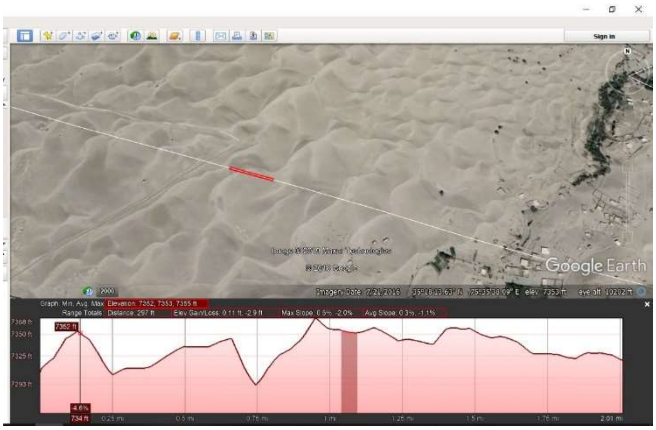

Figure 7. Dune Portfolio (DS 2)

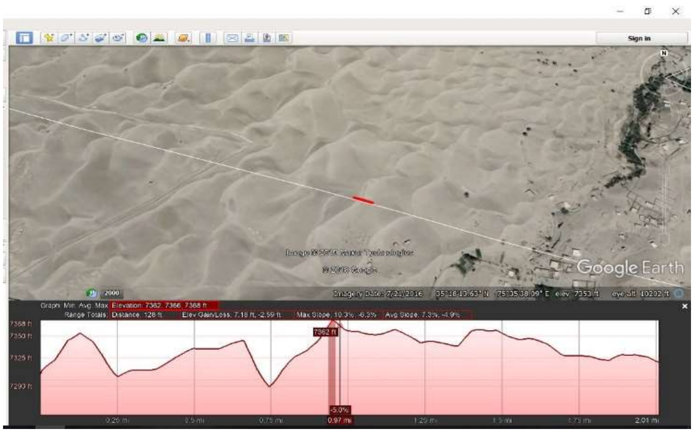

Figure 8. Dune Portfolio (DS 3)

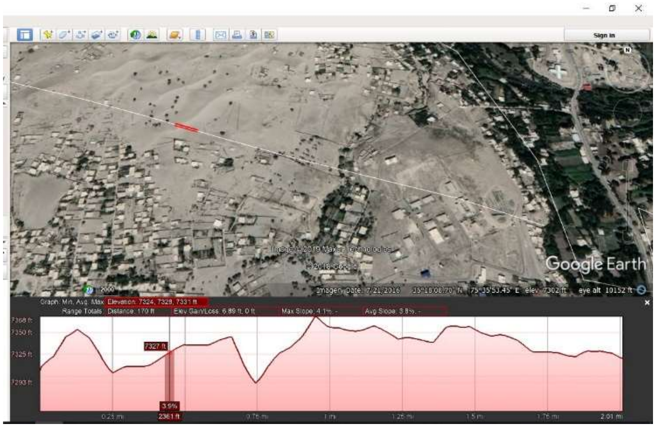

Figure 9. Dune Portfolio (DS 4)

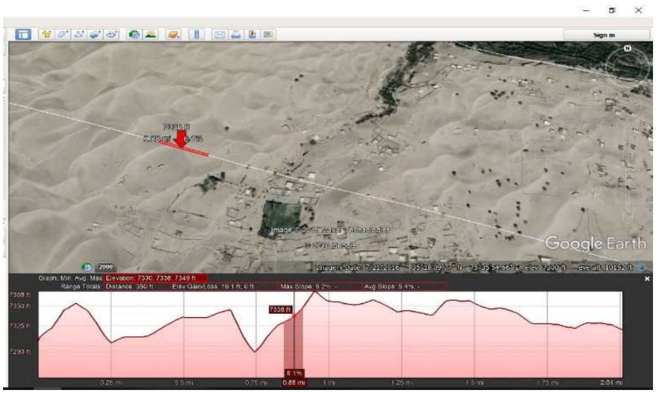

Figure 10. Dune Portfolio (DS 5)

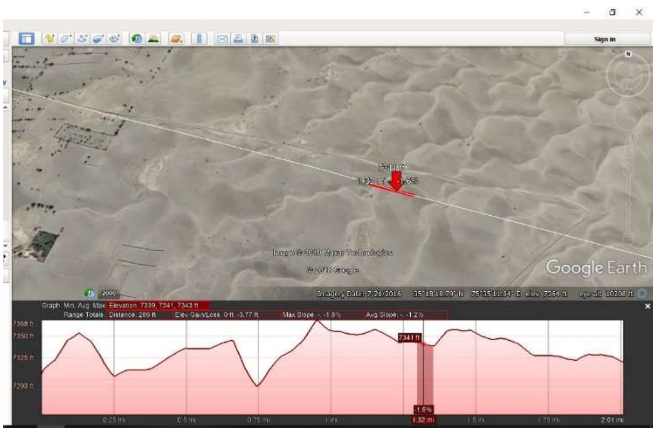

Figure 11. Dune Portfolio (DS 6)

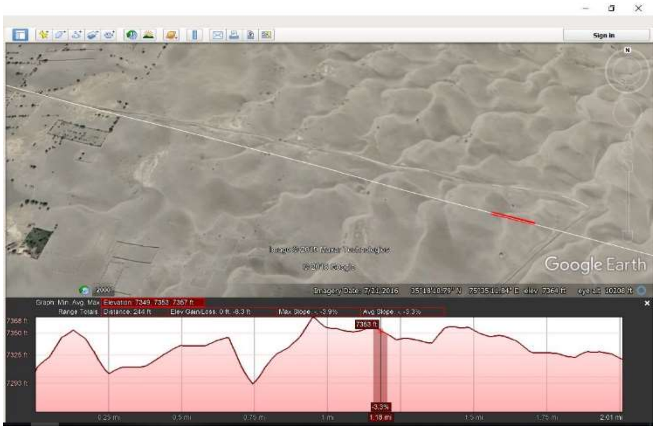

Figure 12. Dune Portfolio (DS 7)

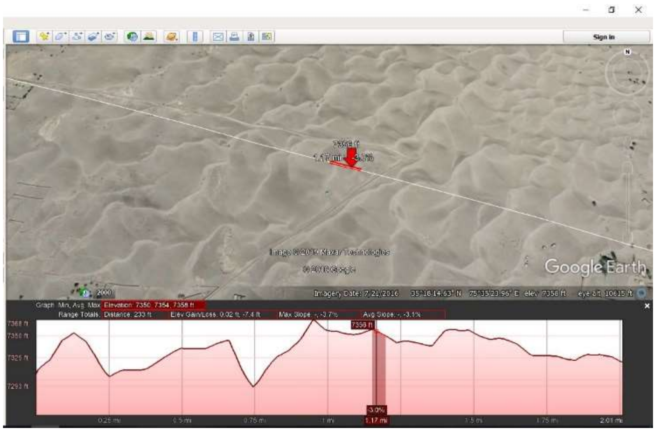

Figure 13. Dune Portfolio (DS 8)

Table 2. Temperature of study area, comparison in mean annual temperature and rainfall from different metrological stations, for the year 2018.

Metrological Stations	Temperature (C^0)	Rainfall(mm)
Astore	18.81947	33.225
Bunji	30.93	10.85833
Gilgit	24.60	7.83
Skardu	21.73432	8.091667
Hisper	24.01909	15.00239

Table 2. The height and width of sand dunes in katpana cold desert

Sr. no.	**Dune Height**	**Dune Width**
D1	7353ft	297ft
D2	7366ft	128ft
D3	7344ft	127ft
D4	7328ft	170ft
D5	7338ft	350ft
D6	7341ft	266ft
D7	7353ft	244ft
D8	7354ft	233ft

CONCLUSION

It is concluded that spatial and physiographic study of the Katpana cold desert is the need of the time, because it is surrounding by strategically important areas of Pakistan. Furthermore, this paper has filled the gap in literature successfully by calculating the area of Katpana (i.e. 9.4 km^2) and by making the portfolio of the dunes. The data of indices has identified the change in the area of Katpana. Variability in the areal coverage of vegetation encourages desert researchers to re-exams of the desertification debate with special reference of the cold desert of Pakistan. It is concluded from the results that climate change is leaving its impact on Katpana cold desert in just three years from 2015 to 2018. Although, it's a positive sign but it draws our attention towards the shift of cryospheric hazard due to atmospheric warming. The snow is melting at rapid pace due to increasing of temperature of the study area and its surrounded lofty snowy mountains in summer season. It disturbs the permafrost equilibrium and warn about the upcoming chain of reactions or atmospheric hazards.

ACKNOWLEDGMENT

Writing a research paper on Katpana desert is bit like gathering some raw materials and through an extensive refining process, shaping that material into a finely reliable piece of research. It takes a great team of skilled and dedicated people to see a concept and turn it into reality. We have been blessed to have just such a team, working with us and appreciate each person who has contributed.

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