



# Economic evaluation of the honey yield from four forest tree species and the future prospect of the forest beekeeping in Sudan

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**Abstract** The present study is an investigation into beekeeping activity values as land use types practiced in Sudanese forests. The main objectives of the study are to estimate honey yield produced per unit area from four tree species, namely: *Acacia seyal*, *A. nilotica*, *Ziziphus spina-Christi* and *Eucalyptus* spp. Furthermore, the study aims at estimating its economic value and financial return (US\$/hectare) using Return On Investment (ROI) as a decision criterion. In addition, the study aims at identifying the obstacles and constraints which this activity faces. The data were collected through interviews with 96 beekeepers in six selected production areas and a survey of market-related data. A structured questionnaire was used, and a descriptive and comparative analysis carried out. The results indicated that the average annual yield of honey/bee hives is 13 kg, ranging between 10 and 16 kg, and *A. seyal* showed the highest productivity. Furthermore, the results showed that 15 bee colonies/hectare is more suitable with a return rate of 780 US\$/hectare annual income. This result indicates that the productivity of honey yield from forest

trees has a considerable economic value and financial return. Thus, these results could be a great incentive to encourage local communities to integrate forest management.

**Keywords** Honey yield · Forest value · Forest management · Forest beekeeping

## Introduction

Sudan's forests are the main source of honey yield production together with other beehive products. While *Acacia* spp, *Ziziphus* spp, *Eucalyptus* spp and *Cordia* spp are the most prevalent, representing 87% of production, only 13% of honey production is obtained from agricultural crops, mostly sunflower and numerous wild herbs and grasses (El-Nebir<sup>1</sup> et al. 2013).

The contribution of forest trees to honey yield is well known in Sudan. Different studies on identification of the botanical origin of honey report the domination of forest tree species as main sources for honey production (Mohammed and Babiker 2010). It has been shown that the botanic origin of propolis, for instance, and its production from *Acacia* spp, *Mimosa* spp, was reported. Furthermore, marketing of honey due to its botanical origin, particularly of honey which originates from *Ziziphus* spp and *Acacia* spp, attracts

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many honey consumers in Sudan and most of the Arab countries (EL-Shehawey 1997; Elzaki and Mohammed 2012).

Beekeeping in Sudan dates back to the 25th Egyptian Dynasty, when the Sudanese King Taharga (688–663 B.C.) became the legitimate Pharaoh of Egypt. At that time, the bee was used as a symbol that denotes King Taharga (Rashad and El-Sarrag 1978). Traditional beekeeping as a type of land use activity in Sudanese forests was established many centuries ago. Based on a survey of the Arab Organization for Agricultural Development (AOAD 1986), about 99% of beekeepers practice beekeeping in the forests and wild areas.

The existence of indigenous species and races of bees in the forest ecosystems is well known. In Sudan, there are many races of honeybee that existed naturally, and this is attributed to the existence of sufficient flowering plant species over the whole country (El-Niweiri and Moritz 2010). Based on that, the forestry sector is a promising area for beekeeping activity. Based on such inputs—for example, in the case of America, apiculture has been proposed in the forest areas, particularly, for small privately owned plots (Hill and Webster 1995).

The history of modern beekeeping dates back to the end of 20th century when Langstroth hive and some of the honeybee races were imported (Rashad and El-Sarrag 1978). Later, many beekeepers and the private sector started commercial production of honey using Langstroth hive and other modern beekeeping equipment. Although Sudan is one of the most important agricultural countries in the world, beekeeping still constitutes less than 1% of the share of agriculture in the economy of the country, which is a very insignificant contribution (Eltoum 1999).

On the other hand, sustainable forest management is considered as an important issue worldwide, particularly in developing countries. Forests provide numerous ecological values and play a vital role in this respect from an environmental perspective. Thus, forest management aims at the permanent preservation of natural resources, an economic perspective which includes the flow of commodities and services. As regards the social perspective, the process would involve communities in decision-making processes as regards forest management and the distribution of forest benefits.

Moreover, there is a high dependency on forests for subsistence or income generation by a large segment of the population in Sudan. Unfortunately, forest management has generally been underscored and miscalculated, although it could play a positive role at all economic levels, e.g., increasing food security and reducing poverty (Reduction 2009). Therefore, great attention should be given to forest management to ensure that there is provisioning with a wide enough range of economic incentives of tangible and intangible sorts to encourage local communities to be involved in sustainable forest management, especially with respect to community-based approaches. These are the biggest challenges facing the forestry sector in the whole country (ElSiddig 2011).

It could be safely stated that non-timber forest products (NTFPs) and trade potentials are sufficient for local people to earn income sufficient to live on (Ruiz Pérez and Arnold 1996; Wollenberg and Ingles 1998). Recently, adding value to non-timber forest products (NTFPs) has become a highly compelling argument for forest conservation. When income generation and commercial exploitation of NTFPs occur, these outcomes could provide an incentive to keep the forest intact and manage it sustainably (Wilsey and Radachowsky 2007). This requires more attention to the important role of the NTFPs because in remote forest areas, they are becoming more and more incorporated with external social, economic and policy networks and their importance in creating alternative employment opportunities.

The importance of forest economic management clearly appears in the objectives of the Nature Conservancy's Center for Compatible Economic Development, which was established in 1995 to develop new businesses, land uses, and products that help to achieve conservation goals (Gilges 2000). One of its programs, the Forest Bank, aims to form partnerships with private landowners to protect the ecological health and natural diversity of working forests while ensuring long-term economic productivity (Dedrick et al. 2000).

Increasing the competitiveness, attractiveness and capacity of the forestry sector is a high priority compared to the other land use sectors. Doing so requires the diversification of financing as well as increased revenues from forest goods and provision of services. Unfortunately, attempts to do so have been faced with diverse and complicated problems, such as:

- Underestimation of the multi-functionality of forests;
- High dependency on timber, which receives greater attention, being the main source of income;
- Unfair division of costs and benefits on the wood chain;
- Long-term of the forestry cycles;
- and the low profit and high risks of investments in forestry (Chipeta and Joshi 2001; van Dijk and Savenije 2009).

## Justification and objectives

### Justification

Sudan has diverse and unique forest resources, which represents an important national asset and heritage. Although there is a high dependency by local communities on forest products and services, there are very few efforts conducted to understand their economic values, the methods of their conservation, and their sustainable management.

Beekeeping, as a type of land use activity practiced in Sudanese forests for many centuries, has not contributed significantly to the economy of the country. Indeed, there are very few official censuses or other official sources of data on it; the activity almost completely lacks the government's attention.

According to Hussein (2000) there are about 50,000 beekeepers in Sudan. With a little attention, these beekeepers could make a considerable contribution to increased revenue from forests and creation of opportunities for promoting beekeeping as an incentive for sustainable forest management. In addition, honeybee colonies could contribute to biodiversity conservation and maintenance, since they are well known for their pollination services for many cultivated crops worldwide (Bradbear 2009; Husselman 2008).

Although the estimations of volume of the wood extracted from forests for fuel wood and charcoal are well studied worldwide (Smith 2001), there are few studies on NTFPs, and non-market values of the forests are estimated in terms of “value per hectare” (Pearce and Pearce 2001).

In Sudan, while forests' production of *Acacia seyal*, *Acacia nilotica*, *Ziziphus spina-Christi*, and *Eucalyptus spp* in terms of timber, charcoal, wood-fuel, and

fruit per hectare have been studied somewhat and economically calculated, there is a complete absence of data on forests' productivity of honey per unit area.

Unfortunately, the majority of forests and woodlands in Sudan still lack sustainable management due to the absence of appropriate forest policies, laws and legislations, institutional frameworks and incentives to promote sustainable forest management (EISiddig 2011).

Also, the few existing plans have clearly failed to achieve the intended objectives due to inadequate funding and lack of technical capabilities, and their limitation to ensuring sustained wood production. Other goods and services that forests offer have largely been neglected, and there is a lack of involvement of local communities (Awimbo et al. 2004).

### Objectives

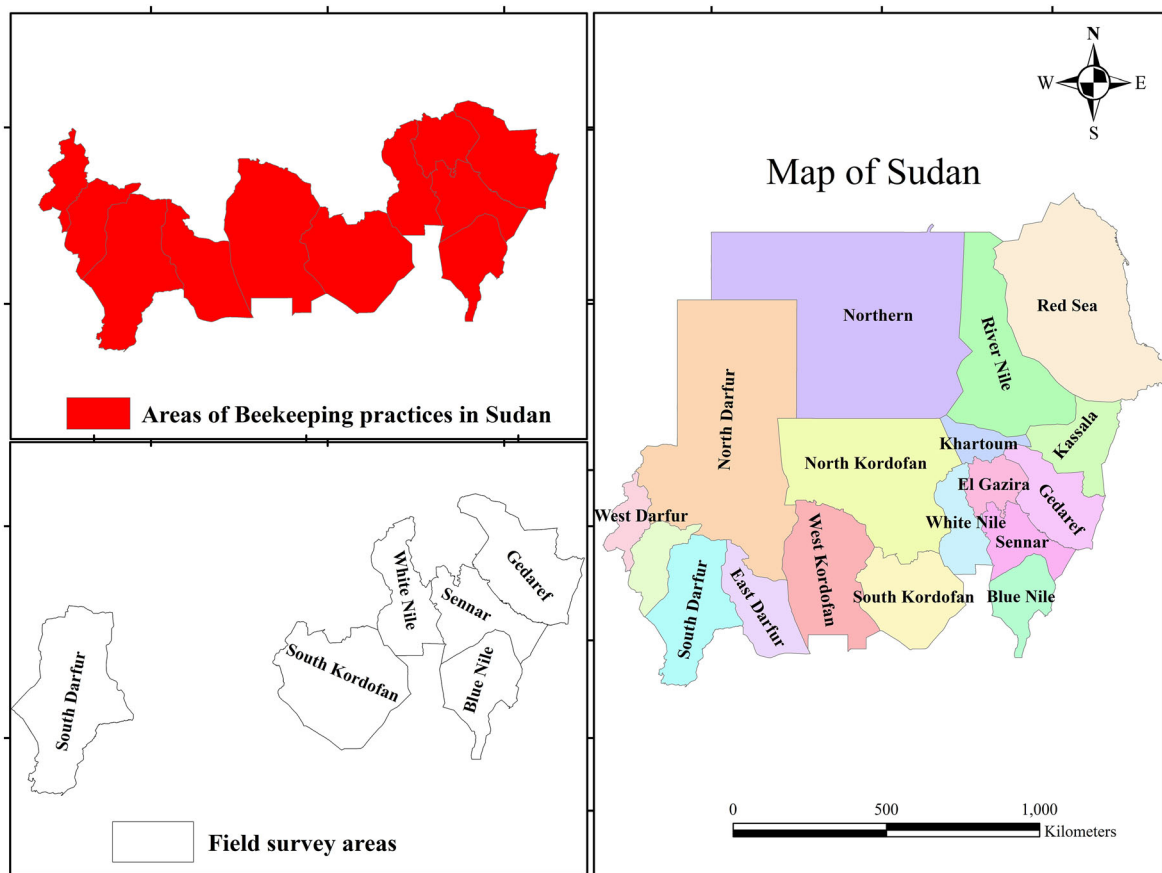
For the above-mentioned reasons, it is necessary to study and understand the strong link between forest resources and beekeeping as a type of land use activity and as an ideal activity in economic, conservation and sustainable forest management programmes. This could be achieved through measuring and assessing the following:

- Estimation of honey yield production from each tree species per hectare (kg/ha/tree species),
- Estimation of the financial return of honey yields' production per hectare from each tree species (US\$/ha/tree species),
- Economic analysis of the revenue of the honey yields from each tree species,
- Investigation of the obstacles and constraints that hinder beekeeping and the highlighting of its future prospects.

## Materials and methods

### Study area

The survey was conducted during the 2014–2015 honey production season in six Sudanese states, namely: Al Gadarif, Sinnar, Blue Nile, White Nile, Southern Kordofan and Southern Darfur. The above regions were chosen among others due to their reputation for honey production (see Fig. 1). In



**Fig. 1** Location of beekeeping and survey samples areas

addition, they are considered to be the largest areas that contain forests of high tree density, and beekeeping activity is practiced widely in them.

#### Data collection and analysis

In this study, questionnaires are the main means of data collection. Some information documented in governmental and non-governmental organizations has also been collected. These latter data sources include documents, files, articles, and annual reports from Forests National Corporation (FNC), state ministries of agriculture and some international organizations.

A purposive sampling technique was used to determine the target population of the study areas. A structured questionnaire was prepared and used to collect the relevant data with regard to beekeeping activity in the selected areas. For identifying and better understanding of this subsector, an initial survey was

conducted to obtain its general characteristics followed by participatory rural appraisal (PRA) approaches. Then, samples of the questionnaire were pretested and modified according to the obtained feedback of the groups. For the data collection, a total of 96 beekeepers were surveyed, with an average of 16 selected randomly in each state. The most important information that was collected included: honeybee forage with emphasis on forest tree species; numbers of beehives per unit area; honey production per hive and prices; and estimated financial return of honey production. Furthermore, major obstacles and constraints of beekeeping are identified.

The questionnaire designed for this purpose attempted to follow basic guidelines: a small number of questions, a limited number of confidential and/or sensitive questions, and the use of a language that respondents feel comfortable with and which they understand in the intended way (Frery 1996).

For data analysis, the Statistical Package for the Social Sciences program (SPSS) was used. Descriptive and comparative analyses were conducted to provide a better understanding of differences and similarities between the four forest tree species in their relation to honey yield that is being estimated.

Estimation of financial return on investment (ROI) of honey yield production kg/tree species/hectare

Estimation of return on investment of honey yield production in kg/tree species/hectare based on a 10-year durability assumption of beekeeping equipment and tools was made as follows:

$$ROI = \frac{\text{Earnings} - \text{Initial investment}}{\text{Initial investment}}$$

where ROI = return on investment; Earnings = revenue per years; Initial investment = costs per years.

### Results and Discussion

Estimation of honey yield production from Langstroth hives by forest tree species

Table 1 summarizes annual honey yield production from the following four forest tree species: *Acacia seyal*; *Acacia nilotica*; *Ziziphus spina-Christi* and *Eucalyptus spp.* Survey results have confirmed that beekeepers completely rely on *Acacia seyal*; *Eucalyptus spp.*; *Ziziphus spina-Christi* and *Acacia nilotica* for their commercial honey production, and their following of migratory beekeeping depends on the flowering season in their area (see Fig. 1. *Ziziphus spp* and *Acacia spp* are identified in many studies for their importance to the honeybees (Al-Ghamdi et al. 2016;

Alqarni 2015), and that was corroborated in our results.

Findings showed that the annual average honey yield per Langstroth hive is 13 kg, ranging between 10 and 16 kg.

This result shows considerable progress in honey production compared to 2 kg honey/colony/year estimated in (AOAD, 1986) survey. However, these figures are still below producers’ goals because of low productivity compared to neighboring countries, such as Ethiopia and Zimbabwe which are similar, to some extent, in the production environment but the annual production exceeds 20 kg/hive (Jenkins and Miklyaev 2014; Nyatsande et al. 2014). There are two reasons for low productivity: (1) beekeepers still lack sufficient experience to manage modern hives for optimum production, and (2) continued deterioration of bee forage. The increase in honey productivity can be attributed to many reasons. Some efforts by local, regional and international organizations have resulted in raising awareness of beekeepers (UNDP 2012), accepting the change to modern beekeeping; also market demand for honey has increased, and hence the quick and high profit earned from this activity.

Based on their experience and knowledge in their area, beekeepers believe that the maximum density of hives per hectare is 10, 8, 7, and 8 for *Acacia seyal*, *Acacia nilotica*, *Ziziphus spina-Christi* and *Eucalyptus spp*, respectively (Table 1). This result shows a very low number of hives/ha when compared to Ethiopia, where it is estimated that each three beehives require an area of about 0.03 hectare (Jenkins and Miklyaev 2014), but it is higher than that of Saudi Arabia, estimated as 2 hectares for one hive (Al-Ghamdi et al. 2016). Lack of experience of beekeepers in modern beekeeping has a great influence upon the hives’ distribution. Therefore, experimental studies are recommended for this issue supported by more

**Table 1** Honey yield production by Langstroth hive/kg from forest tree species

Annual average net of honey yield/hectare = 780 US\$

Tree species	Honey yield kg/hive			Number of hives/hectare			Honey price US\$/kg Mean
	Min	Max	Mean	Min	Max	Mean	
<i>Acacia seyal</i>	3	5	4	10	18	14	4
<i>Acacia nilotica</i>	2	4	3	10	16	13	4
<i>Ziziphus spina Christi</i>	3	4	3.5	12	18	15	6
<i>Eucalyptus spp</i>	2	3	2.5	12	24	18	2
Mean	3.25			15			4

investigations, particularly (AOAD 1986) survey estimates of a ratio of 12.5 hectares/colony in the cultivated area of Sudan.

#### Financial return and estimation of return on investment (ROI) in beekeeping from forest trees

Based on the results obtained from interviews with beekeepers and market surveys, inputs' types and quantities are shown in Table 2. The annual incomes per hectare (US\$/ha) from *Acacia seyal*, *Acacia nilotica*, *Ziziphus spina Christi* and *Eucalyptus spp*, respectively, are 224 US\$/ha, 156 US\$/ha, 315 US\$/ha and 90 US\$/ha. Inputs and outputs of investment in forest beekeeping for honey yield (US\$/ha) are shown in Tables 2 and 3. The ROIs of honey yield production from *Acacia seyal*, *Acacia nilotica*, *Ziziphus spina-Christi* and *Eucalyptus spp* are 46%, 29%, 69% and 12% respectively. These percentages are considered low, to some extent, and that is due to the high input costs of initial investment of 401 US\$ per hive compared to 250 US\$ as stated by Kaiser and Erns (2013). Management and operation costs constituted more than 50% of the total cost. This result agrees with Michael (2008), who states that in Nigeria labor costs accounted for about 64% of total costs, in addition to the lower productivity per hive, because most of the beekeepers still lack sufficient experience to manage modern hives for optimum production.

Obstacles and constraints of the forest beekeeping and its future prospect from a beekeeper's point of view

Table 3 shows the obstacles and constraints as stated by the beekeepers. These can be divided into the following categories:

*Production inputs costs* 96% of the beekeepers claimed that input costs were very high, and its effect appears on their honey production and could lead to the collapse of modern beekeeping completely. The ranking of this category's items is as follows: first, beekeeping equipment and tools; secondly levies and fees; thirdly management and operation cost; fourthly, transportation costs (Table 3). The problem of high input costs faces many countries worldwide, particularly developing countries where these countries depend on imported beekeeping equipment (Haftu 2015; Okwee-Acai et al. 2010).

*Bee's habitats and foraging area* The majority of the beekeepers are aware of bee habitat problems. These habitat problems include wildfires, agricultural expansion, deforestation and forest degradation, the spread of insecticide use and the increased migration rate of the bee colony as a result of the above-mentioned problems (see Table 3). The rapid spread of wildfires is common in Sudan's forests and range land, primarily because of the long dry season and lack of inspection and fire lines (Bayoumi 2001; Hamza 2016). Also, extensive use of agricultural mechanization directly increased horizontal expansion that contributed to the forest areas' destruction and other

**Table 2** Inputs of honey production from one apiary (25 hives) for 10 years: wy = worker/year

Year	Item	Unit	Quantity	Cost (US\$/unit)	Total cost (US\$)
1	Langstroth box	Box	25	35	875
	Honeybee colony	Colony	25	35	875
	Wax foundation	kg	10	5	50
	Honey extractor	Piece	1	150	150
	Protective clothe	Piece	2	30	60
	Smoker	Piece	2	5	10
	Tools	Piece	4	3	12
	Management & operation and guarding	wy	1	600	600
2–10	Management & operation and guarding	wy	9	600	5400
	Others or unseen 5% of the total cost	5%	9	222	1994
Sum					10,026

Total cost of one hive for honey production = 401 US\$

**Table 3** Obstacles and constraints of the forest beekeeping

Category	Obstacles and constraints	Frequency	%
Production inputs costs	Management and operation cost	92	96
	Beekeeping equipment and tools	96	100
	Transportation cost	86	90
	Levies and fees	96	100
Bee habitats and foraging area	Wildfires	96	100
	Deforestation and forest degradation	82	85
	Agricultural expansion	90	94
	Spread of insecticide use	68	71
	Migration of bee colony	60	63
Beekeeping as general	Low prices in the production area	83	87
	Lack of credit	72	75
	Lack of technical assistance	94	98
	The absence of the state's interest	96	100
	Lack of the beekeeper's awareness	64	67

vegetation (Elnagheeb and Bromley 1994; Shazali 1999). Wildfires and agricultural expansion are the main causes of deforestation and forest degradation, which leads to direct and rapid destruction of the honeybee's forage habitat.

All beekeepers interviewed complained of wildfires and their quick and direct effect on bee forage and colony migration. They ascribed such reasons to the lack of concern for forest management and the absence of fire lines. The above-mentioned reasons could be attributed to the limitation of forest management plans and lack of appropriate forest policies, legislation, institutional frameworks and incentives to promote sustainable forest management (ElSiddig 2011).

### Beekeeping in general

The results of interviews conducted with beekeepers have revealed the existence of some obstacles and constraints whose influence could affect the entire activity. The beekeepers summarized these obstacles as follows:

Firstly, absence of government interest; the core problem of this subsector is that it is subject to administrative conflicts where its administration is shared between the Ministry of Agriculture, the Ministry of Animal Resources and the Forests National Corporation (FNC). The direct impacts of these conflicts are, first, the lack of technical assistance provisioning and lack of credit facilities, which negatively affect this sector, Secondly, there is a lack

of technical assistance; this includes assistance to facilitate optimal use of modern beekeeping equipment for better bee product extraction, storage and packing, as well as to enhance ability of the beekeepers to deal with honeybee pests and diseases. Thirdly, there is a lack of available credit for purchase of modern beekeeping tools and equipment, an especially difficult situation for young beekeepers and beginners. Fourthly, there is inadequate knowledge and experience in the case of many beekeeper; the results showed that almost of the beekeepers are not aware about honeybee biology, local forage of the bees and nectar flow, and lack knowledge and techniques of colony manipulations for the different bee products and pollination services. Finally, there are low prices throughout the production area; most of the beekeepers have no choice but to sell their production away from their production area due to their small production quantities and difficulties to access consumption areas. Therefore, prices are controlled by the existing local retailers, which it is always at the lowest level.

Beekeepers' obstacles and constants in Sudan are similar to those of beekeepers in neighboring countries, such as Ethiopia and Nigeria who face such problems as droughts and wildfires, lack of capital, technological assistance and bee management skills, in addition to the absconding and migration of the bee colony (Michael 2008; Shibru et al. 2016). Moreover, Sudan beekeepers face the same problems of marketing and absence of policy in this activity as Ethiopian beekeepers (Ejigu et al. 2009).

## Future prospects and promise of forest beekeeping

All interviewed beekeepers confirmed that forests are the backbone of their activity, and everything affecting forests positively or negatively directly affects their activity. Forest beekeeping practice always has a positive effect economically and environmentally (Bosma et al. 2017; INGRAM 2011). Therefore, great attention is required by the Forests National Corporation (FNC) based on its responsibility of forest management in the country as representative of the government.

Beekeeping activity revenue is not insignificant, and therefore, if forests are managed properly, and plans carefully applied, beekeeping could be a good source of additional revenue that can help in reducing forest management costs, which is considered to be the main obstacle to forest sustainable management (Boscolo et al. 2010).

Furthermore, having a source of income can encourage local communities to participate in the forests' management and conservation, particularly when we know that this activity is practiced in remote rural areas where minimum requirement of the management is unavailable.

## Conclusion

Sudanese beekeepers depend on forest trees as the main source for their honey production and keeping honeybee colonies. Our results concluded that 15 bee colonies/hectare is the suitable average with a return rate of 780 US\$/hectare annual income. This result indicates that the honey yield from forest trees has considerable economic value and financial return but is still below beekeepers' ambitions. Administration of the beekeeping subsector in our study area was shared between the Ministry of Agriculture, the Ministry of Animal Resources and the Forests National Corporation (FNC). These three government institutions are responsible for solving the major constraints for this activity, such as: conservation of habitats and forage areas; technical assistance; and to give more attention to this activity. Furthermore, they are highly encouraged to create strong partnerships between governmental agencies, national and regional organizations and local communities to achieve considerable promotion and progress. Forests national

Corporation (FNC) is highly recommended by beekeepers to play a significant role in this sector. However, FNC lacks support of policies and legislation, which regulate and organize beekeeping activity, but it has a huge opportunity to implement incentives to introduce beekeeper communities into the integrated forest management system.

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