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Review

Artificial insemination in Botswana: Challenges and opportunities - A review

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ABSTRACT: Artificial insemination (AI) was introduced in Botswana in 1966 to provide smallholder cattle farmers with access to superior bulls for cross-breeding to improve their herd quality and performance. This review endeavours to highlight farmers' uptake of AI service, challenges and the opportunities in the use of AI technology in Botswana. The 15 AI centres have been underutilised for the past 11 years while the number of inseminated cows has declined over time. Similarly, conception rates declined as these are a function of inseminated cows. Some major challenges limiting AI utilisation are persistent drought, outbreak of livestock diseases and parasites, climate change, inadequate extension service, high transportation costs, shortage of qualified ranch managers, inadequate transport, inadequate staff accommodation, lack of maintenance of fire breaks and perimeter fence at the AI centres, and trekking cows over very long distances to the AI centres for insemination. The underutilisation of AI centres presents an opportunity for farmers to send their cattle for insemination. In order to optimally use the AI service, extension efforts must be directed towards encouraging more farmers to use the AI centres.

Keywords: Artificial insemination, assisted reproductive technologies, cattle, conception rates, smallholder farmers.

INTRODUCTION

Agriculture provides food, income and employment for the majority of the rural dwellers in Botswana (Statistics Botswana, 2016). About 70% of the rural households in Botswana derive their livelihoods from agriculture, through subsistence farming (Statistics Botswana, 2012). The agriculture's share of gross domestic product (GDP) in Botswana is estimated to be 2.2% (Honde, 2018) compared to over 40% at independence in 1966. Over 80% of the agriculture's share of GDP is contributed by the livestock sub-sector, indicating that it plays an important role in the country's economy.

Livestock, especially cattle which account for 80 to 85% of the agricultural output is the backbone of agriculture in Botswana (AfDB/OECD, 2003; GAIN Report, 2015). Cattle are a major source of wealth and income (World Bank, 1977). The beef sub-sector is one of the most important economic activities in Botswana on which a large proportion of the population depends for their livelihood (Buck et al., 1975), in particular the rural populace. According to Statistics Botswana (2019), the cattle population in the traditional sector declined from 1.4 million in 2015 to 1.1 million in 2017 representing a decline of 21.4%. The decline is attributable mainly to persistent drought, inadequate technical support, diseases and parasites stock theft, as well as, conversion of livestock farms to game farms (Department of Animal Production Report, 2017/18).

According to Morrell (2011) and Patel et al. (2017), AI is the manual placement of semen in the reproductive tract of the female by a method other than natural mating. Assisted reproductive technologies such as AI, super ovulation, *in vitro* fertilization and embryo transfer are used

to overcome reproductive challenges, to increase the offspring from selected females and to reduce the generation intervals in farm animals (Vikrama and Sri Balaji, 2010). Artificial insemination speeds up genetic progress, reduces the risk of transmission of diseases and increases the number of animals that can be bred from a superior parent (Patel et al., 2017). Artificial insemination was originally developed to control the spread of animal diseases, by avoiding the transport of live animals with potential pathogens to other animal units for mating and by avoiding physical contact between individuals (Kubkomawa, 2018). Thibier and Wagner (2002) estimated that approximately one fifth of the world's breedable female population is bred by AI.

In Botswana, the use of AI in cattle dates back to the mid-1960s when the technology was introduced to improve herd quality, particularly in beef animals. As high quality bulls are expensive for smallholder farmers to purchase, Government introduced AI to give farmers the opportunity to improve herd quality without the need for a bull (Moreki and Ranko, 2011). Artificial insemination is cheaper and offers farmers choice of breeds through the use of semen. Semen obtained from different bulls can be purchased, stored and used over a long period of time compared to a bull that might die. Buck et al. (1975) stated that AI was viewed in Botswana as a useful method of introducing crossbred progeny into the national herd but not as a major method of breeding.

Although AI and embryo transfer are indispensable tools for genetic improvement as they play an effective role in propagating improved breeds (Malafosse, 1990), it seems that the benefits of utilising AI are not accruing to a large proportion of farmers in Botswana due to inter alia underutilisation of AI centres and low uptake by ranchers. Therefore, this review highlights farmers' uptake of AI service, challenges and the opportunities that exist.

ARTIFICIAL INSEMINATION AND ITS DEVELOPMENT IN BOTSWANA

Artificial insemination is the main and in most cases the only, reproductive or molecular technology in Africa. Its use is reported by all countries of East and Southern Africa, and by 74% of the countries in North and West Africa (FAO, 2015). Although worldwide AI has been practised in cattle for a long time, it was introduced in Botswana in 1966 to provide smallholder cattle farmers' access to superior bulls for cross-breeding purposes (Bucks et al., 1975). At the time of its inception, the AI service was organised and coordinated by the Department of Veterinary Services of the then Ministry of Agriculture (now Ministry of Agricultural Development and Food Security). Currently, AI service is under the Department of Animal Production which offers a course where participants learn how to perform AI in order to use it on their own farms (FAO, 2015). Two 3-weeks AI courses each with an intake of 30 participants are conducted on annual basis. As shown in Figure 1, there are 15 AI centres spread across the country to which livestock farmers can send their cattle for insemination. Table 1 shows the areas served by each of the AI centres. Bucks et al. (1975) attributed the success of AI service in Botswana to Dr. A. S. Jensen who was instrumental in its establishment.

During the initial stages of AI development, frozen semen was purchased from South Africa. However, semen imports have decreased significantly over time as semen is now produced locally at the Ramatlabama Bull Stud in the Southern District. Semen imports fluctuate due to breakdown in equipment used for semen collection and processing at the Bull Stud. Presently, there are 16 bulls that are used for semen collection at the Bull Stud (Table 2). Semen from Sussex, Brahman, Simmental, Charolaise, Brown Swiss, Friesian, Jersey, Santa Gertrudis, Ayrshire, Limousine, Bonsmara, Mosu and Tswana breeds are available for use by farmers. This indicates that semen for both dairy and beef cattle is available.

Table 3 gives data on semen production in Botswana over an 11 year period. All the semen produced at Ramatlabama is used locally. Semen processing at the Bull Stud is inadequate due to the type of equipment used as it is old. As shown in Table 3, no semen was produced from2014/15 to 2018/19 mainly due to equipment failure. The shortfall during the four year period (i.e., 2014/15 to 2018/19) was met from residual semen harvested over time.

ARTIFICIAL INSEMINATION PROGRAMMES

There are two AI programmes that are undertaken in Botswana: static and on-farm AI. Static AI is operated by Government at subsidised prices for smallholder livestock farmers while on-farm AI is for farmers capable of doing AI at their ranches and/or holdings. The two AI programmes are discussed in the sections below.

Static AI

In Government AI centres, it costs P20 (USD1.8) per cow (i.e., P10 for semen and another P10 as upkeep fee). A farmer is allowed to bring a maximum of five cows which are inseminated with locally produced semen. The price of imported semen is usually higher than that of local semen. Presently, the breeding programme in Botswana runs from November to March of each year.

Figure 2 shows that the number of inseminated cows at AI centres has declined over time. A sharp decrease in the inseminated cows was observed in 2014 followed by 2011 and 2016. From 2008 to 2018, inseminated cows and those that conceived have on average been declining by 127.9 and 185 cows per annum, respectively. Similarly, conception rates declined as these are a function of

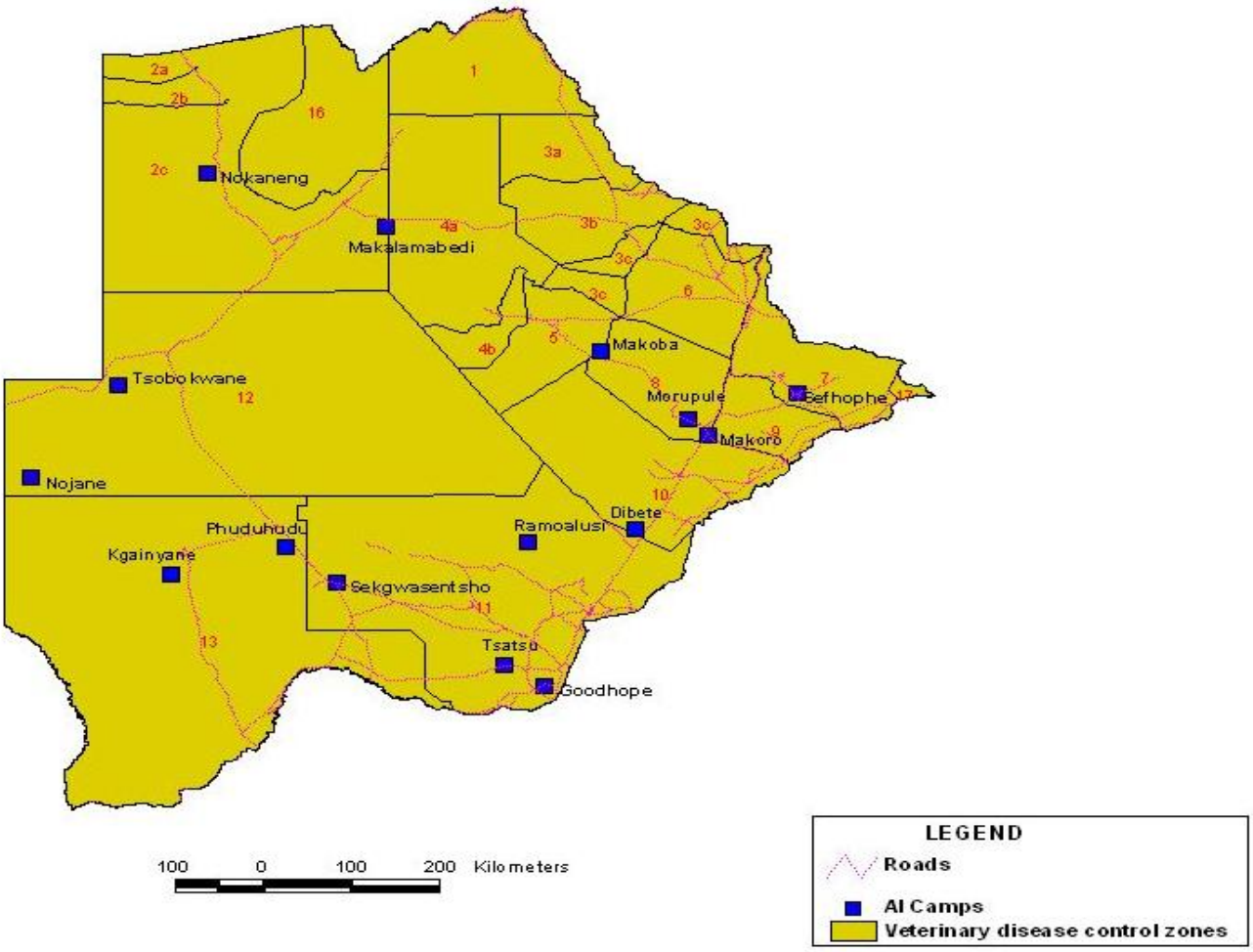

Figure 1. Map of Botswana showing artificial insemination centres.

Table 1. Artificial centres, size and area served.

AI centre	Area (hectares)	Area served
Nokaneng	6400	Ngamiland
Makalamabedi	6400	North West and part of Boteti
Makoba	2809	Most of Boteti sub-district
Morupule	4117	Central district
Makoro	1600	Palapye and part of Tswapong south
Sefophe	3600	Bobirwa and Tswapong north
Dibete	6672	Mahalapye and Kgatleng
Ramoalosi	5813	Kweneng district
Tsatsu	3765	Southern district
Good Hope	690	Borolong area
Sekgwasentsho	6400	Ngwaketse west
Kgainyane	6400	Kgalagadi north
Phuduhudu	6400	Kgalagadi south and north
Ncojane	6400	Gantsi south
Tsobobokwane	6400	Gantsi north
Total	15	73 866

Source: Adapted from Mocheregwa (2016).

Table 2. Breed and number of bulls used for semen at Ramatlabama.

Breed	Number of bulls
American Brahman	4
Santa Gertrudis	4
Charolaise	3
Limousine	2
Simmental	2
Mosi	1
Total	**16**

Source: DAP Database.

Table 3. Data on semen production at Ramatlabama Bull Stud.

Year	Semen production(doses)	Semen distribution	
		Static AI (doses)	On-farm AI (doses)
2018/19	0	7253	4797
2017/18	0	6054	3975
2016/17	10971	4703	4776
2015/16	0	7836	2258
2014/15	0	6562	7129
2013/14	17359	11080	2235
2012/13	16928	9452	2789
2011/12	22872	11332	2621
2010/11	50563	10355	3373
2009/10	17018	13429	5557
2008/09	66580	12803	6006

Source: Ramatlabama Bull Stud database.

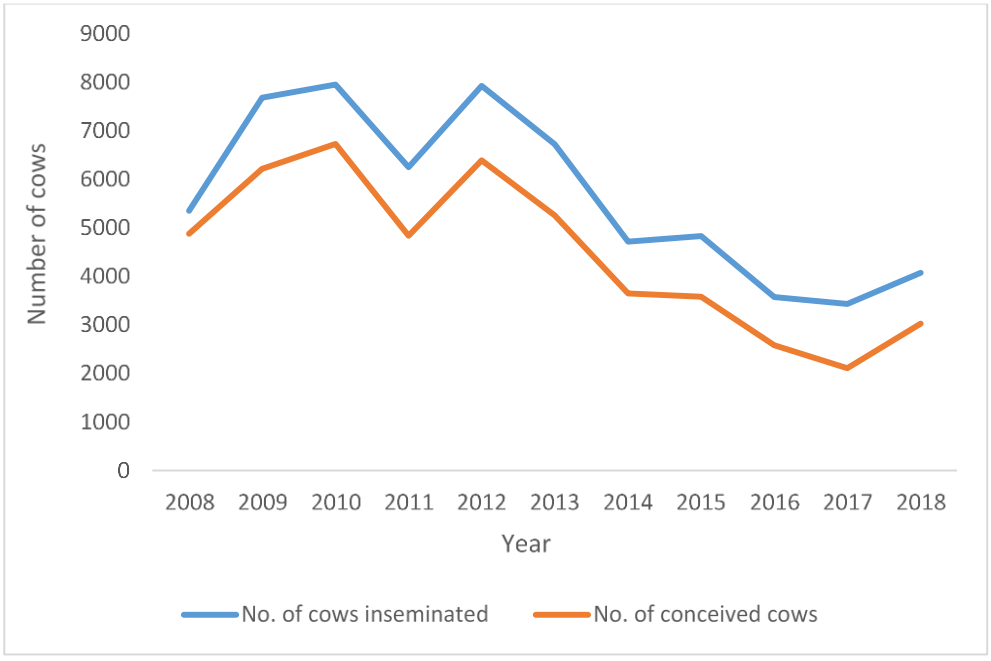

Figure 2. Cattle entered at AI centres from 2008 to 2018.
Source: Department of Animal Production Reports (2008/09 to 2017/18).

inseminated cows. The highest conception rate (91%) was achieved in 2008 and the lowest in 2017 (61%) due to severe drought. The average conception rate is 77.36%. The decline in conception rates could be attributable to the degrading of AI centre, as well as, late and erratic rainfall. In the opinion of Bucks et al. (1975), the maximum utilisation of the AI facilities is limited by the time the cattle spend within the AI centre. The minimum time for oestrus detection, insemination and subsequent pregnancy diagnosis would seem to be three months, and frequently with delayed onset of oestrus and repeat services can be for about six months. This could be due to the fact that cows are brought to AI centre not in good body condition due to exposure to poor nutrition.

The study by Potdar et al. (2016) reported that conception rate is directly associated with the production attribute and that it monitors life time productivity of the individual animal. As a result, conception rate determines the profitability of farm enterprises. The authors found that conception rate of the cows was significantly affected by cattle breed, sire breed, heat stage, AI sequence number and lactation number but reported no significant difference due to body condition of animal. Nutrition is one factor that influences conception rates in cattle prior to and post parturition. The authors reported the highest conception rate in early heat stage (43.64%) compared to when insemination was done in mid heat stage (38.24%), indicating that conception rates decreased in late heat stage. Lack of nutrition before calving gives rise to cows becoming thin at calving, thus delaying the onset of oestrus activity after calving.

On-farm AI

On-farm AI was introduced in 1994 to provide AI services to private farmers at highly subsidised rates (Mocheregwa and History). The programme was first piloted in Tribal Land Grazing Policy ranches at Jwaneng and Francistown ranches to augment the Government run static AI programme. The objective of on-farm AI scheme is to encourage farmers with fenced ranches to use the AI technology. Government promotes the use of on-farm AI by providing free inseminator training and technical advice to farmers who use this technology. The programme was extended to other parts of the country in 1996. Although there are 170 registered on-farm AI farmers throughout the country, their participation in the programme varies from year to year with an average of 60 farmers (35.3%) participating per year (Department of Animal Product Report, 2017/18).

The farmers' participation in the programme varied from year to year due to various reasons ranging from persistent droughts, failure to keep inseminators due to low wages, and lack of commitment by some farmers. The programme resulted in the establishment of two community AI ranches in the country, one at Phanyana in Southern district and the other one at Masama in Kgatleng district. Phanyana ranch was established in 1996 and has the capacity to enter 600 to 800 cows per breeding season. However, it is underutilised all the time. Masama ranch was established in 1939 as a Community Trust but started AI service in 2005 and inseminates 60 to 100 cows per breeding season.

As the dairy sub-sector performance is unsatisfactory, Government in 2014 took a deliberate decision to provide dairy farmers with imported semen (sexed and ordinary semen) at subsidised prices in order to improve the sub-sector's performance. The main concern is low numbers of dairy cows/herd and lack of quality genetics. Other services offered by Government under the programme are the bull performance testing at a minimum fee, free technical advice on available reproduction technologies across other livestock species and promotion of stud breeding.

CHALLENGES TO THE USE OF ARTIFICIAL INSEMINATION

The use of AI by farmers in Botswana is hampered by a number of challenges which are discussed in this section. Moreki and Ranko (2011) reported lack of maintenance of fire breaks and perimeter fence at the AI centres, inadequate supply and high cost of liquid nitrogen for storing semen, shortage of qualified ranch managers, and inadequate transport, as well as, inadequate staff accommodation to be challenges in the use of AI service. However, the price of liquid nitrogen is currently low due to the establishment of the liquid nitrogen plant by Government in 2016. In most AI centres, the maintenance of fire breaks is carried out annually and forage in the fire breaks area regenerate during the course of the year, thus making them unable to control veld fires from entering the AI centres. Failure to maintain fire breaks leads to destruction of the ranch by veld fires thus resulting in the ranch not being used until it recovers from the damage. This has a deleterious effect on the AI service delivery to farmers, especially smallholder farmers. Mocheregwa (2016) identified veld fires and farmers' ignorance about AI to be the challenges in the delivery of AI service. Veld fires influence the number of cattle that enter AI centres. For example, Makoba AI camp was destroyed by fire in 2008 and 2010 resulting in the camp not being used until it recovered. The fire occurred due to lack of fire breaks management of equipment due to financial challenges. The fact that some farmers are not aware of AI service points to the inadequacy of extension support.

Underutilisation of the AI centre is a major challenge in using AI technology (Moreki and Ranko, 2011). As mentioned earlier, there are 15 AI centre around the country with a total carrying capacity of about 11 000 cattle and these are being underutilised. Over the past 11 years the 15 AI centres were on average utilised at 63.5% (i.e.,

6 983 cows) per annum. Forage in some AI centre is not able to support optimum use of the ranches due to degradation, overgrazing, destruction by veld fires or bush encroachment.

In a recent study, Mocheregwa (2016) reported trekking cows over very long distances and limited and/or no access to the AI centre to be limiting factors to the use of AI service by farmers. Some AI centre are located very far from farmers and this limits their use mainly to farmers situated nearer to the AI facility. As the majority of smallholder farmers cannot afford to transport their cattle to the AI centre due to high transportation costs, they resort to trekking them leading to cows loosing body condition. This gives rise to some cows being fatigued upon arrival and failing to conceive. In agreement with this finding, Mushonga et al. (2017) reported that the distance from the AI camp influences the farmers' choice of AI or natural service. The authors found that AI adoption by small-scale farmers was greatly influenced by accessibility to AI centre, i.e., most farmers within a walking distance adopted AI technology while those situated over 15 km away from AI centre preferred natural service. This implies that shorter distances promote the use of AI service than longer distances. Longer distances to AI centre result in higher transportation costs to farmers and low utilisation of AI service.

According to Buck et al. (1975), the common challenges of AI in developing countries are poor stockmanship, communal grazing, oestrus detection, and poor communications. Over 80% of cattle in Botswana are grazed on unfenced communal rangeland while the remainder is grazed in fenced ranches. Due to inadequacy of technical support provided by the Government extension service to farmers, poor stockmanship remains a major challenge in livestock production. This has to be addressed if livestock productivity is to be raised significantly.

Frequent occurrence of drought significantly reduces cattle population resulting in few cows entering AI centres for insemination (Mocheregwa, 2016). Drought affects forage quality and quantity, as well as, water availability for livestock often leading to loss of body condition and mortalities. In addition, opportunistic diseases usually occur leading to economic losses. Outbreaks of diseases, especially Foot and Mouth Disease (FMD) impact negatively on the performance of the AI centres and the livestock industry in its entirety. According to Derah and Mokopasetso (2005), FMD is World Organization for Animal Health (OIE) list A disease which seriously affects livestock production in southern Africa. In controlling FMD the country is divided into risk zones (green and red) and appropriate disease surveillance, livestock identification and movement restrictions and control in the different risk zones are put in place. In addition, vaccination is carried out in the designated vaccination zones. The outbreak of FMD leads to movement restrictions and at times stamping out, thus reducing the number of cattle entered in the AI centres for insemination. In addition, pest infestation as is the case with the current outbreak of African bont tick (*Amblyomma gemma*) in the Gumare area of the North West District results in livestock movement restrictions being enforced to contain the pest. Other factors include heavy dependence on Government for funding and human resources.

OPPORTUNITIES

It is evident from Figure 2 that the AI centre are underutilised and this presents an opportunity for smallholder farmers who cannot afford to purchase a bull to send more cattle for insemination. For these AI centre to be optimally used, it is necessary that funds are made available to enable their refurbishment. Furthermore, opportunities exist for the private sector, farmer associations, university graduates and academic institutions to participate in the delivery of AI service to farmers. This should contribute to employment creation, especially for young animal science graduates. An opportunity exists for the local agricultural university to develop short-term practical courses in AI for both technicians and farmers.

CONCLUSION

Artificial insemination is the most popular reproductive technology for cattle producers in Botswana, especially smallholder farmers with smaller herd sizes. Some major challenges limiting farmers use of AI service include inter alia persistent drought, outbreak of livestock diseases and parasites, climate change, inadequate extension service, limited funding and trekking of cows over very long distances to the AI centres for insemination. Although the AI centres are not optimally utilised by farmers, they are not enough to accommodate more cattle for insemination. The underutilisation of AI centre provides an opportunity for farmers to benefit from AI services provided by the Department of Animal Production by sending more cattle for insemination. The Ministry could use radio and Television programmes, as well as, print media such as DailyNews paper, Agrinews and Iketleetse magazines to disseminate information on AI service to farmers. To optimise the use of AI service, extension efforts must be directed towards educating farmers about the benefits of using AI service, as well as, encouraging them to utilise the AI technology.

Recommendations

1. Extension efforts should be directed towards encouraging farmers to fully utilise the AI centres by bringing more cattle for insemination. Therefore, extensive farmer education relating to the use and benefits of using AI service must be conducted.

2. Training of AI technicians/inseminators and farmers must be intensified. Refresher courses should be organised for AI technicians on regular basis. In addition, finance should be made available to enable technicians to participate in AI courses offered outside the country such as those organised by the University of the Free State and University of Pretoria in South Africa.
3. Government, farmer associations, the private sector and development agencies should work together to make AI accessible to all farmers in an effort to improve the quality of livestock in the country, especially cattle. It is through the use of AI technology that throughput to the export abattoirs could be increased.
4. Artificial insemination technology should be extended to other livestock species such as equines, sheep, goats, pigs and poultry. This will involve training of technical staff and farmers.
5. For AI to gain country-wide usage it is necessary that AI value chain is developed involving relevant stakeholders.
6. The AI facilities for cattle should be established to increase semen production. Furthermore, the performance test programmes to produce the best bull/stud for AI is important and should be supported by the government.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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